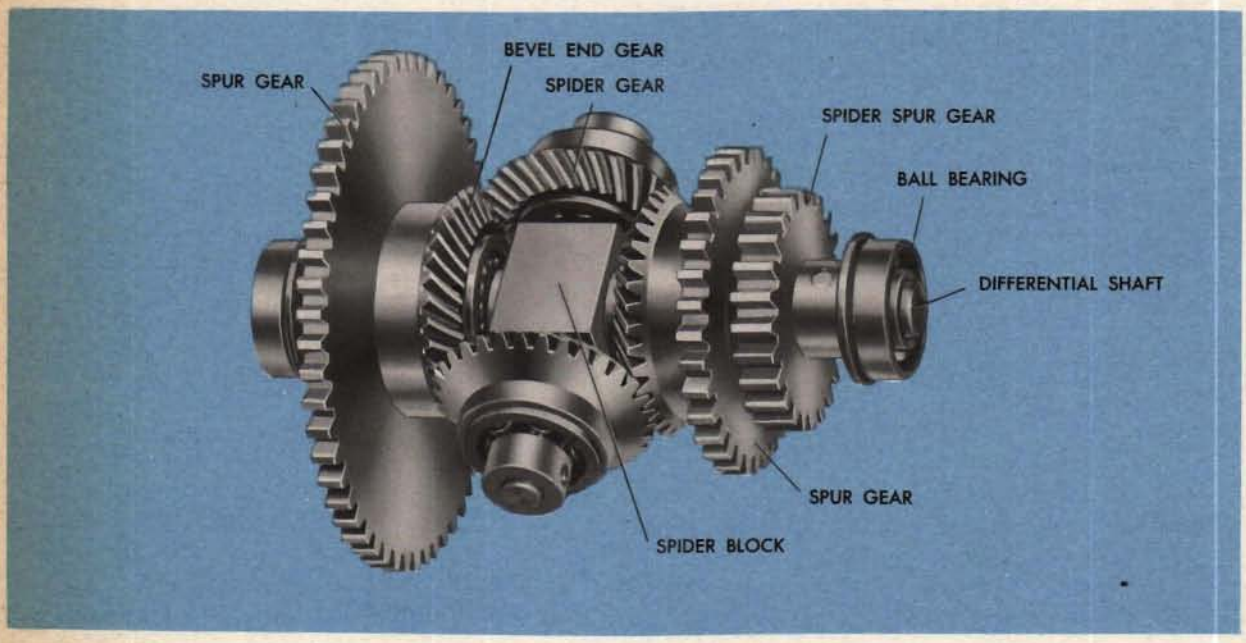
THE BEVEL GEAR DIFFERENTIAL



As a general rule, a differential suspected of causing faulty operation should not be removed from the instrument unless the particular cause of the trouble has been found in it and the repair cannot be made in place.

Nearly every differential shown on the instrument gearing and schematic diagrams bears a number which is also stamped on the spider block of the corresponding differential in the instrument.

Typical symptoms

Test analysis and unit check tests may have indicated that a certain differential is not operating properly. Check the differential for the following typical symptoms:

JAMMING: Gears ordinarily free to turn cannot be turned; or turning one gear turns them all.

STICKING: A definite tight spot, or bind, is felt in one or more of the gears.

EXCESSIVE LOST MOTION: The differential turns freely, but when the input gears are held, more than normal lost motion is felt in the output gear.

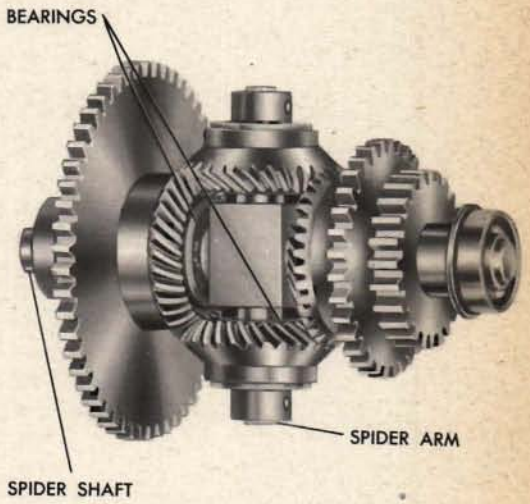
SLIPPING: Turning either input gear does not turn the output gear.

Locating the cause

Jamming or sticking

Differential jamming or sticking may be caused by a bent differential shaft or spider arm, damaged gear teeth, defective bearings, or dirt or chips between gear teeth. Try to determine by inspection whether one of these defects is causing the trouble.

It may be possible to remove foreign matter from the gear teeth while the differential is still in place. Making any of the other repairs, however, requires removal of the differential from the instrument. Damaged gears or defective bearings must be replaced. A bent shaft or spider arm may be removed and straightened if it is not bent too much.



Excessive lost motion

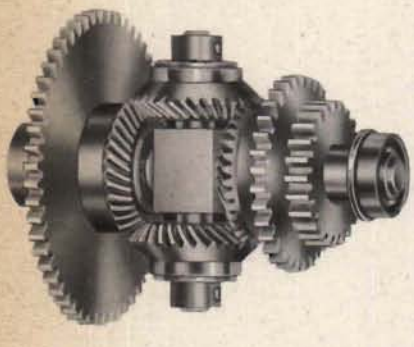
Excessive lost motion may be caused by worn bevel-gear teeth or incorrect reassembly of spacers. To reduce lost motion, the differential must be removed and disassembled.

Slipping

A differential may slip if the bevel-gear teeth are stripped, a spur gear slips on its hub, or a taper pin is sheared or missing from the spider block. Repair will require removal of the differential.

Removing a differential

A differential may be a part of a unit or a shaft line. Frequently units can be removed from the instrument and disassembled on the bench in less time than it takes to disassemble them in place. Study the location of the differential in order to decide whether removal of the entire unit or of the differential alone will take less time and work. Remember that removing the differential may disturb the relationship of at least three shaft lines, but removing a complete unit may disturb many more. The instrument schematic and gearing diagrams must be consulted to determine how many lines will be disturbed. Consult the instrument OP to see whether there are special instructions for removing any particular differential.

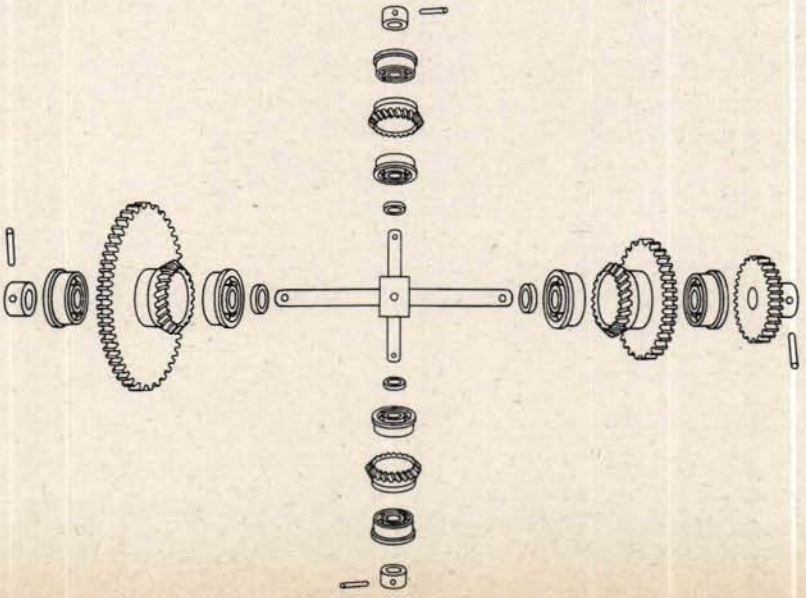


A COMPLETE DIFFERENTIAL

It is important to remove or reinstall a differential as a unit wherever possible, in order to avoid disturbing the bevel-gear meshes. Often frictions or other mechanisms are mounted on a differential shaft, but the actual differential includes only the parts illustrated here.

Differentials are made in three common sizes, according to the shaft diameter: 5/16, 1/4, and 3/16 inch. The spider gears on the two larger differentials are held by taper-pinned collars. On the 3/16-inch differential, each spider gear is held by a spacer and a snap ring which fits into a groove in the shaft.

To disassemble a 5/16 or 1/4-inch differential, drive out the taper pins at the ends of the shaft and the spider arms. On a 3/16-inch differential, remove the snap rings. Remove all the parts from the shaft and the arms, one at a time, and place them in rows on the bench in their proper order for reassembly. *Be sure to keep each spacer and taper pin with its part.*



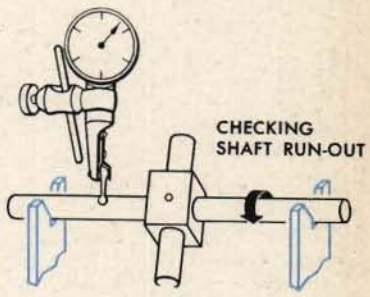
A DIFFERENTIAL DISASSEMBLED

Repairing the parts

Straightening a shaft or spider arm

Remove all the parts from the shaft except the spider. To check the shaft for run-out, mount it on V-rests on a surface plate and use a surface gage and a dial indicator. The maximum allowable run-out is 0.0005 inch total indicator reading. Straighten the shaft as described in the chapter on *Basic Repair Operations,* pages 68 and 69.

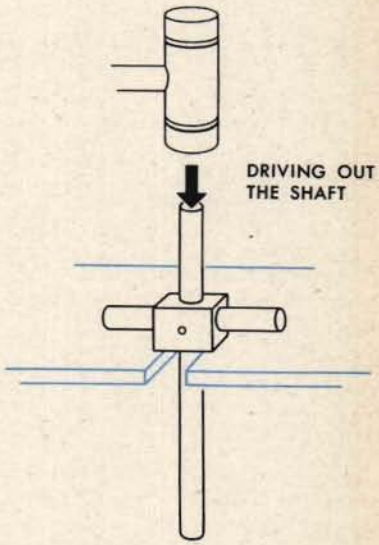
The run-out check for the spider arm is the same as for the shaft, and the same method of straightening is used. A spider arm should be replaced if it is bent more than 0.002 inch.



CHECKING SHAFT RUN-OUT

Installing a new shaft

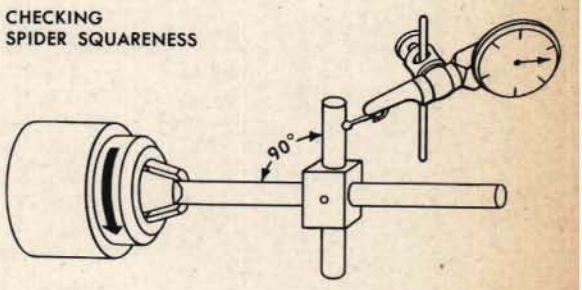
Tap out the spider-block taper pin and gently drive out the shaft with a plastic hammer. Insert the new shaft in the spider, reaming the hole only if necessary. Install an oversized taper pin. If necessary, polish the shaft to make it fit the end-gear bearings.



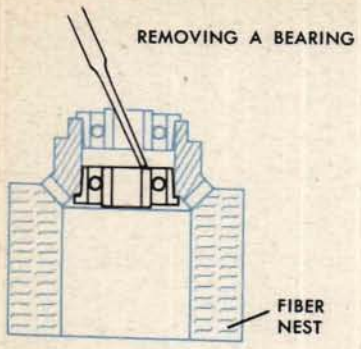
DRIVING OUT THE SHAFT

Checking the squareness of the shaft and spider

After it has been determined that the shaft and spider arms are straight, the squareness of the spider arms must be checked with a dial indicator. To do this, support the shaft in such a way that it can be rotated without either lengthwise motion or run-out. Position the indicator against the side of one spider arm. Turn the shaft and note the two readings as the spider arms pass the indicator. The difference between the readings should not exceed 0.0005 inch. If the difference is greater, the spider must be replaced.

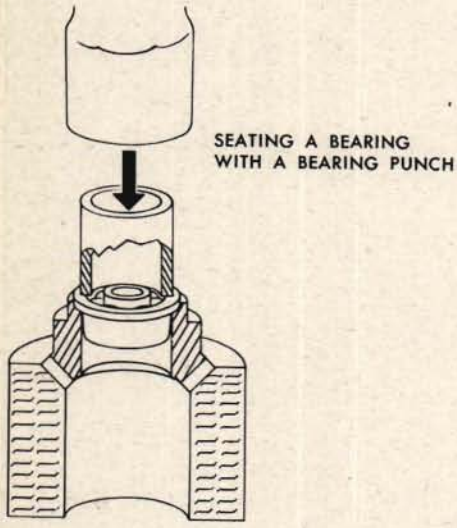


CHECKING SPIDER SQUARENESS

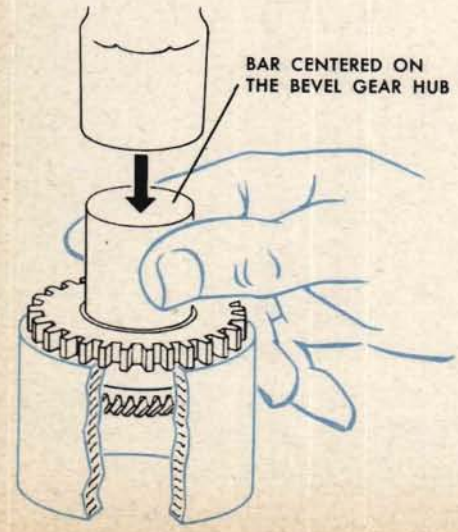


Removing and replacing bevel-gear bearings

If special bearing pullers are not available, the first bearing can be started out of its seat by tapping the inner race. To avoid damaging the gear teeth, hold the gear in the hand, or place it in a conical nest of fiber or bakelite. Insert a 1/16-inch straight punch through the shaft hole in the first bearing to reach the inner race of the second bearing. Tap lightly and uniformly all around the inner race until the bearing drops out. Use a bearing punch to remove the other bearing.



Seat new bearings with a bearing punch.

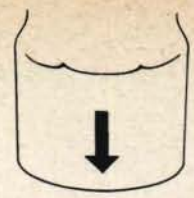


Removing a spur gear from a bevel end gear

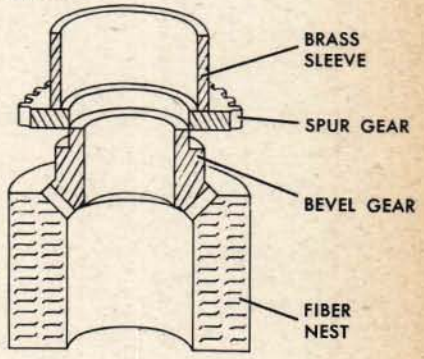
With sufficient care, spur gears can be removed without damaging the end gears. Keeping the protruding hub of the bevel gear on the top side, place the spur gear in a cylindrical nest of fiber or bakelite. To remove the bevel gear, center a brass tube or bar, slightly smaller than the hole in the spur gear, on the bevel gear hub. Tap the bar with a light hammer until the bevel gear drops out of the hole.

Replacing a spur gear or bevel end gear

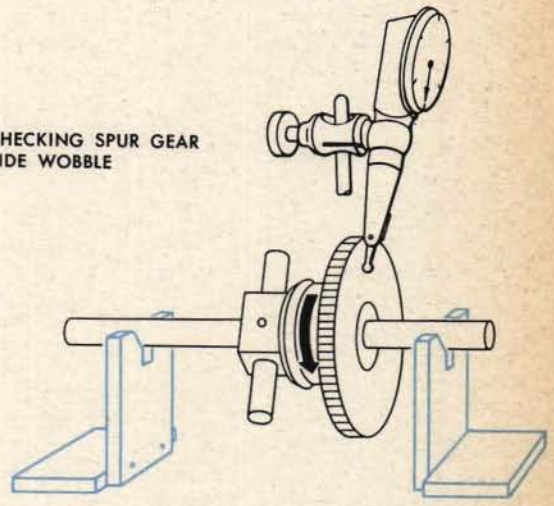
After inspecting the gear teeth to make sure there are no defects, clean both the end gear and the spur gear. Before fitting a new spur gear, remove the sharp edge from the hub of the bevel gear. Start the spur gear onto the bevel gear hub by hand. Now rest the end gear on a bakelite or fiber nest, and with a brass sleeve and a light hammer, tap the spur gear onto the hub. Make sure that the spur gear is fully seated against the shoulder on the bevel gear hub.



SEATING THE GEAR

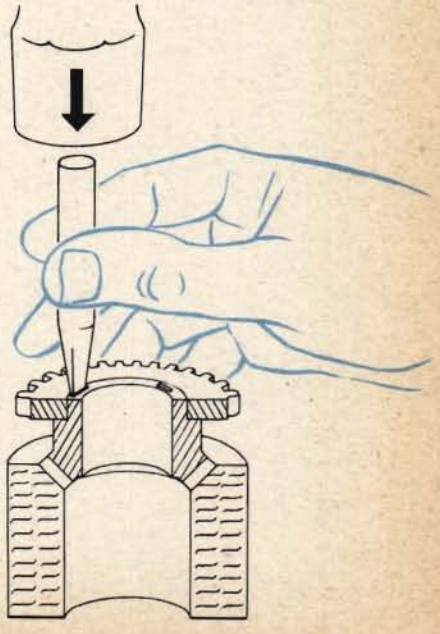


Now mount the gear assembly on the shaft, and with a dial indicator check the spur gear for wobble. If wobble is excessive, check the seating of the spur gear against the shoulder.



CHECKING SPUR GEAR SIDE WOBBLE

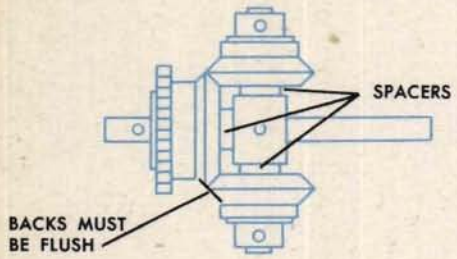
Examine the staking in an assembled differential to see how it is done. Use a sharp chisel to stake the spur gear to the bevel gear in the same way. Dowel these parts as described in the explanation of doweling, pages 74-75.

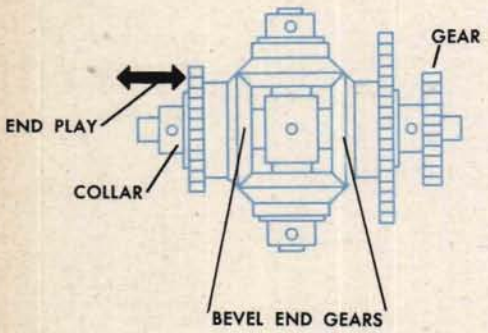


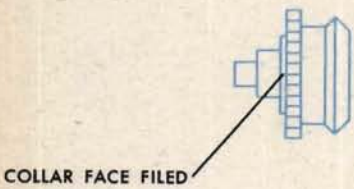
STAKING

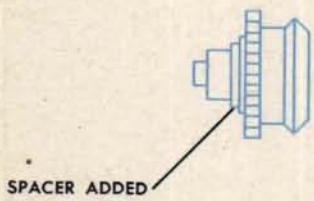
If a new end gear is used, the bearings must be fitted to it. Seat them with a bearing punch, supporting the gear in the hand or in a fiber nest in order not to damage the teeth.

Reassembling the unit









1 Using the particular spacer which belongs between each gear and the spider block, mount both spider gears on the spider arms and one end gear on the shaft. If any new parts have been used to repair the differential, new spacers may be required.

2 Fit the spacers to make the backs of the bevel gears flush and to remove nearly all lost motion. If the meshes are only *slightly* rough they can be improved by running-in the gears at step 7.

3 Now remove the first end-gear assembly and mount the other, correcting its mesh by fitting only its particular spacer. Do not alter the spider-gear spacers. When the gears mesh properly, replace the other end-gear assembly on the shaft.

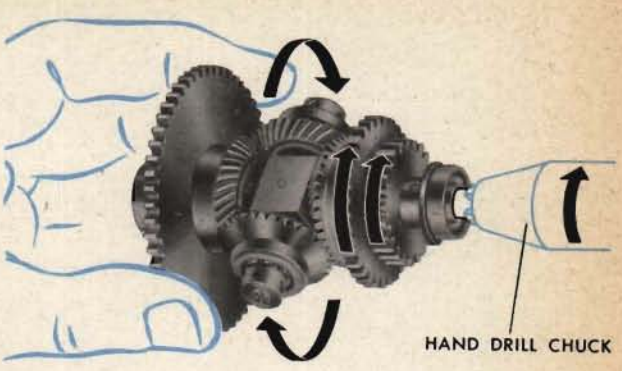
4 Add the collar and the gear which position the bevel end gears, and set them carefully to avoid end play. If a new shaft is used, it is preferable to use new collars. If the original parts are used, it may be necessary to fit new spacers.

5 Insert the taper pins and tap them lightly to hold them in place. If a new shaft has been used, first drill the taper pin holes but do not ream them until step 9.

6 Check the spider gears and the bevel end gears for end play. If necessary, fit spacers to eliminate end play or file the collars to allow free running of the bearings.

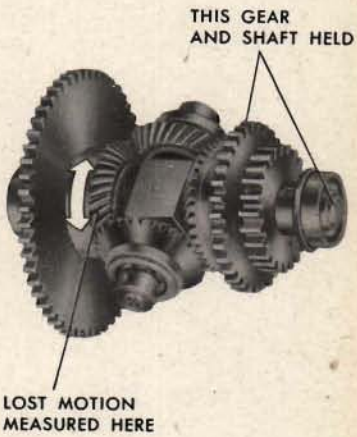
7 Lubricate the four bevel gears and run them in. If necessary, coat the teeth with running-in compound, very lightly, so that it will not fly off and get into the bearings.

8 Run-in the bevel gears by rotating the shaft by hand or with a hand drill. Rotate each end gear separately for about a half-minute while holding the opposite end-gear assembly stationary. Be careful not to allow the compound to enter the bearings during this operation, and afterward wash the whole assembly thoroughly with an approved solvent.



9 Finish hand-reaming each taper pin hole and fit all the taper pins. Seat the pins, but do not stake them until after all the gear meshes have been checked for smoothness and lost motion.

10 If fully seating the pins has caused any of the meshes to tighten, or has increased the end play of any gear, readjust by filing the face of the collar or by adding a spacer. All gears must be completely free on their shafts, but without end play. Each bevel gear mesh should have less than 0.0005-inch lost motion. The reassembled differential should now run freely and coast to a slow stop.



11 Use an indicator to measure the total lost motion at the pitch line of one bevel end gear when the other bevel end gear and the differential shaft are held stationary. The allowable maximum of total lost motion is shown on the assembly drawing for each differential.

12 Now stake the taper pins, making sure to support the parts directly under the staking tool. After staking, the differential should be checked for lost motion, end play, and smoothness of operation. Finally, wash and lubricate the entire differential assembly.

THE JEWEL DIFFERENTIAL

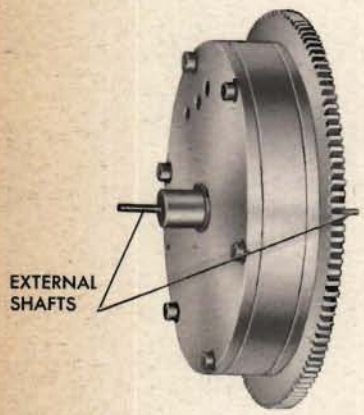
LARGE JEWEL DIFFERENTIAL

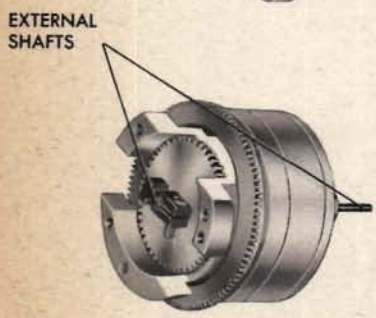
SMALL JEWEL DIFFERENTIAL

A jewel differential is a spur gear differential. It has the same function as a bevel gear differential, but is used where low inertia is required and where the load is light. Jewel differentials are usually mounted in electromechanical units. The large type is used in double-speed receivers, and the small type in the time motor regulator.

A jewel differential is a delicate piece of equipment and should always be handled with great care.

The spider is built up around the gears to form a protective case. The small steel shafts are mounted in cup bearings made of a synthetic jewel or a special steel. To protect these external shafts, the differential should always be supported on blocks so that the shafts never touch the bench.





Typical symptoms

If the operation of a jewel differential is faulty, look for one or more of these typical symptoms:

JAMMING AND STICKING: An external shaft resists turning.

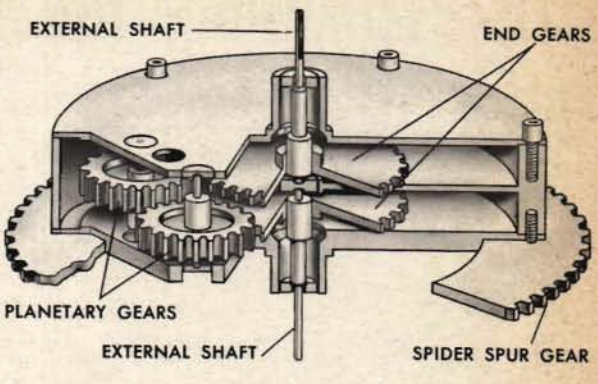
SLIPPING: When the spider and one external shaft are held, the other shaft can be turned.

EXCESSIVE LOST MOTION: When the spider and one external shaft are held, excessive lost motion can be felt in the other shaft.

Locating the cause

Four aluminum spur gears on steel shafts form the internal gearing of the jewel differential. The internal gearing should turn freely when slight torque is applied to an external shaft.

Because the gears of a jewel differential are enclosed in a case, it is often difficult to locate the cause of faulty operation. Each gear and shaft should be checked since there may be more than one source of trouble. It is advisable to remove all the gears and then reinstall each end gear singly to check its bearings and shaft. After this, reinstall each end gear with its mating planetary gear to check the gear mesh, the bearings, and the shaft of the planetary gear.



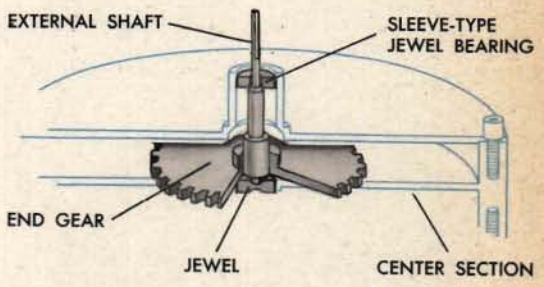
Jamming and sticking

One gear alone may jam or stick because of insufficient end play, a burred pivot point, or dirty or damaged jewel bearings.

A gear may jam or stick if a jewel bearing has shifted sufficiently to allow the shaft to slip out of the cup in the jewel. A shifted jewel may allow an end gear to rub against the center section or on the side of the planetary gear with which it does not mesh.

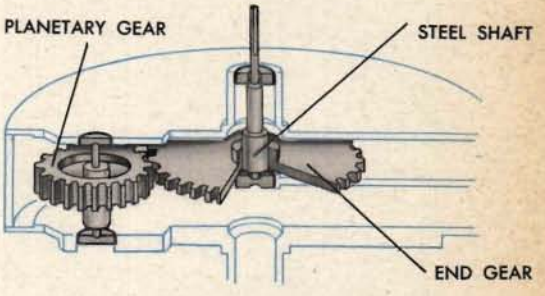
An external shaft may bind because of damage to its shank or its sleeve-type jewel bearing.

Two meshing gears may jam or stick because of dirty or damaged teeth.



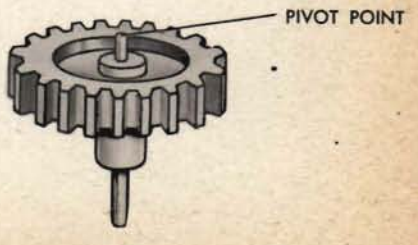
Slipping

An aluminum gear may slip because it fits loosely on a steel shaft. It may slip out of mesh if its shaft pivot point is broken or if its jewel bearing has been jarred loose or shifted sufficiently to allow the pivot point to slip out of the cup in the jewel. If a gear slips out of mesh there will usually be a rough and sticky feeling when the end shafts are turned by hand.

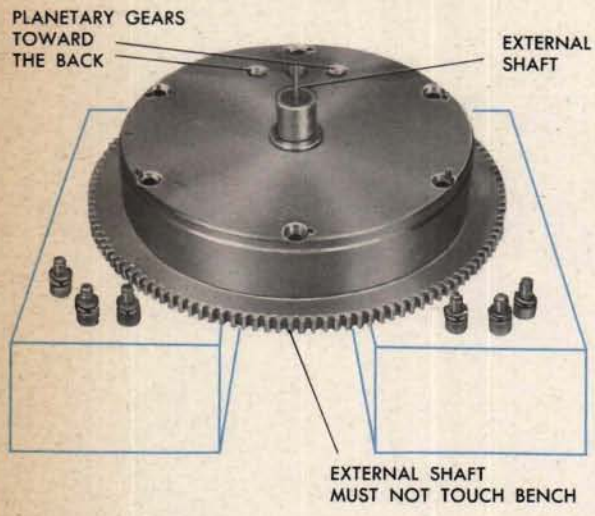


Excessive lost motion

Excessive lost motion in the gear meshes may be caused by wear. Worn gears must be replaced. Excessive lost motion accompanied by a feeling of roughness when the end shafts are turned by hand may be caused by a broken pivot or a damaged jewel.

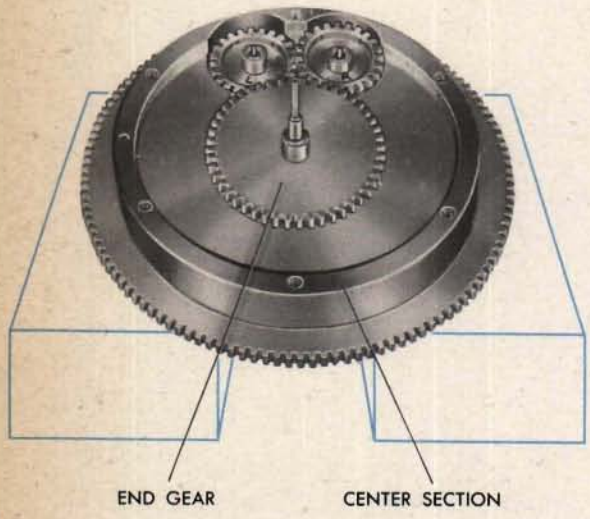


Disassembling the large jewel differential

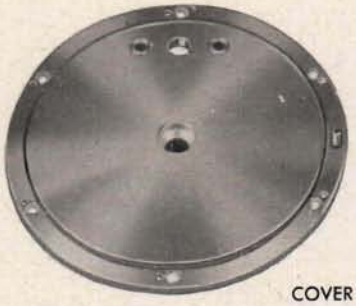


1 Support the differential on two blocks, with the cover on top and the planetary gears toward the back.

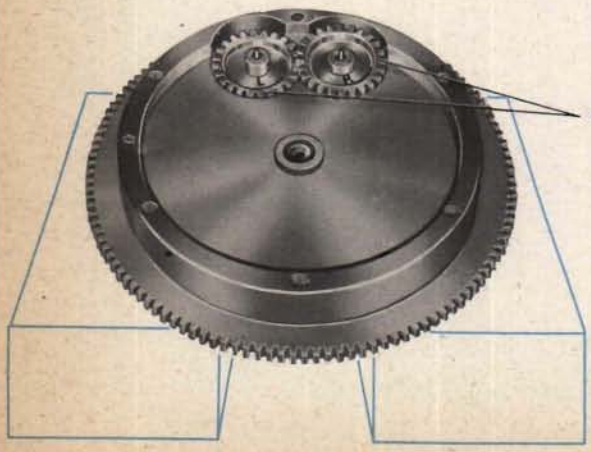
2 Remove the six screws, lock washers, and lug washers holding the cover to the center section.



3 Remove the cover.

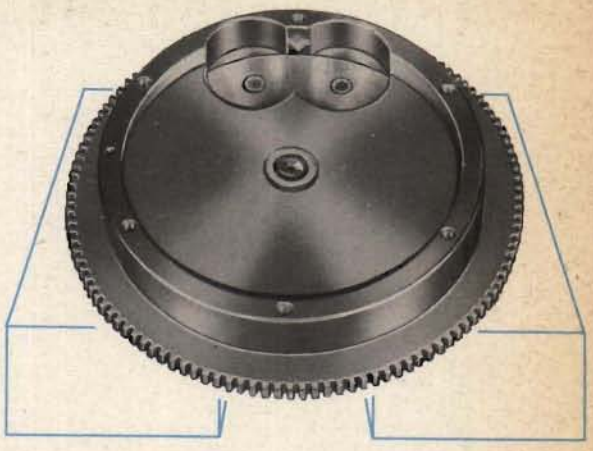

COVER (REMOVED)

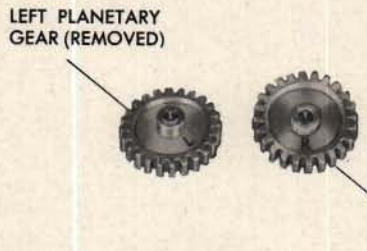
4 Lift out the end gear and tag it.




END GEAR (REMOVED)

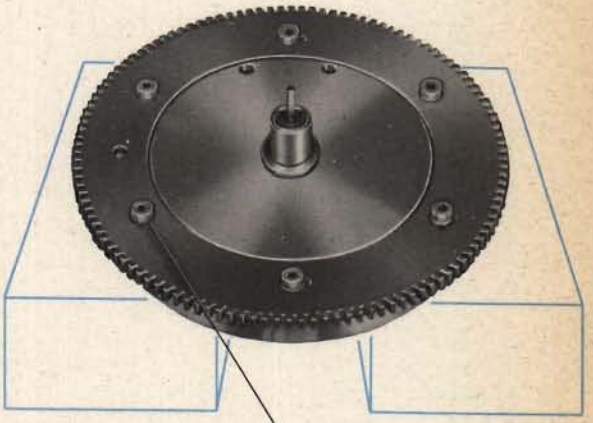
5 Remove the right planetary gear. If it is not marked, tag it. The smaller hub of this gear faces the cover. (In some differentials the smaller hub of the left planetary gear faces the cover. In either case do not interchange the planetary gears.)





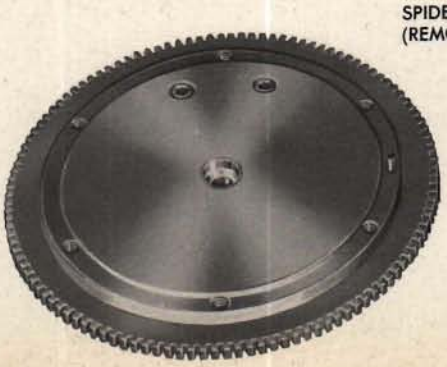
6 Remove the left planetary gear. If it is not marked, tag it. The larger hub of this gear usually faces the cover.

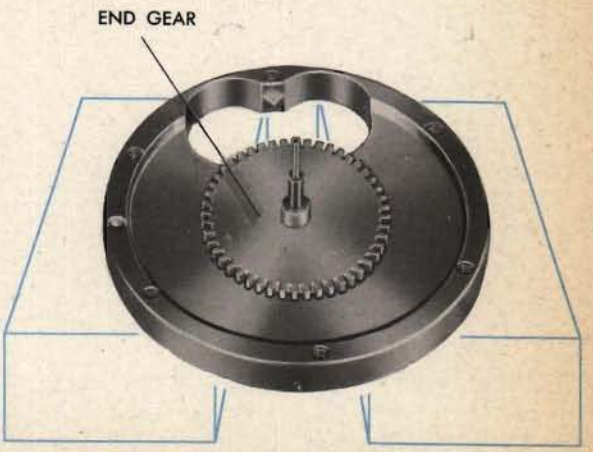
7 Invert the assembly and remove the six screws holding the spider spur gear to the center section. These screws are longer than the ones holding the cover.



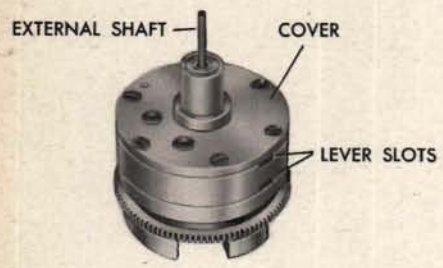
8 Remove the spider spur gear assembly which is doweled to the center section.

9 Remove the end gear and tag it. The shaft in this end gear is equal in length to the shaft in the other end gear, but the flat is shorter.



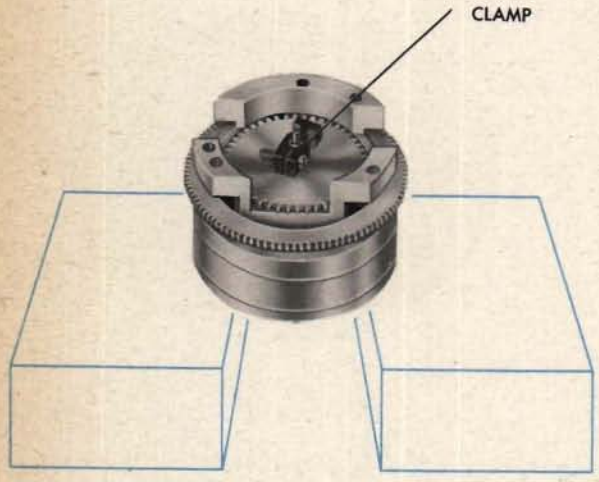


Disassembling the small jewel differential



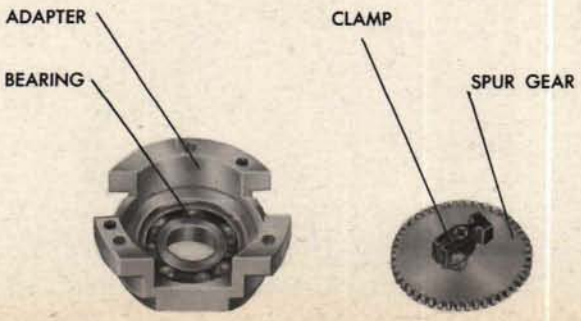
1 Remove the flat-head screws.

2 Invert the differential and support it on two blocks to prevent damage to its external shafts. The planetary gears should be toward the back.

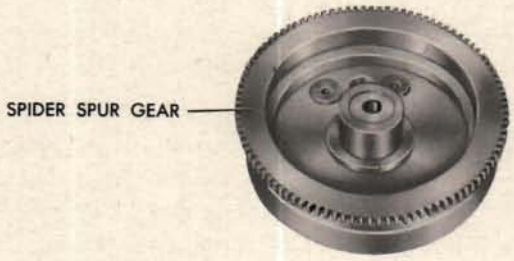


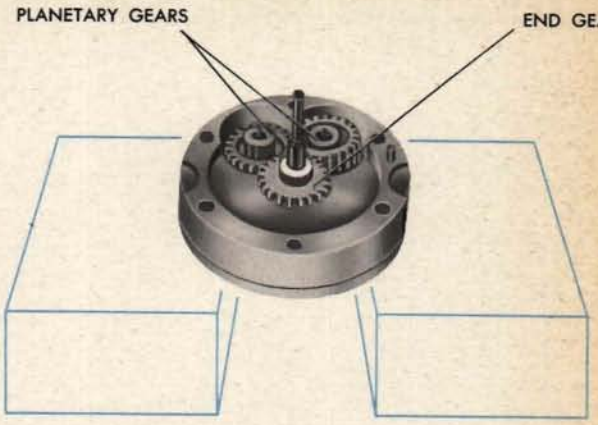
3 Loosen the clamp. Remove the clamp and spur gear together.

4 Remove the adapter and bearing.



5 Remove the spider spur gear.

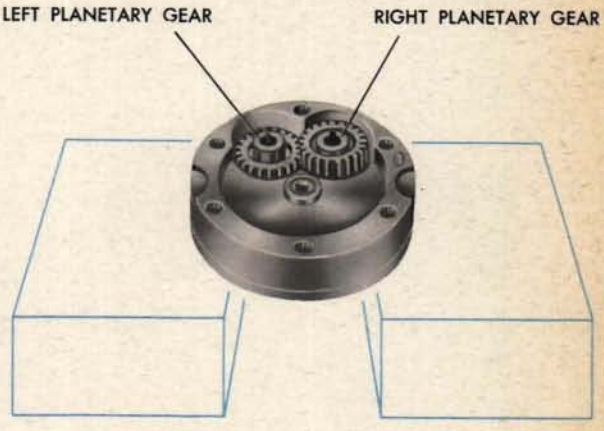




6 Lift out the end gear and tag it.

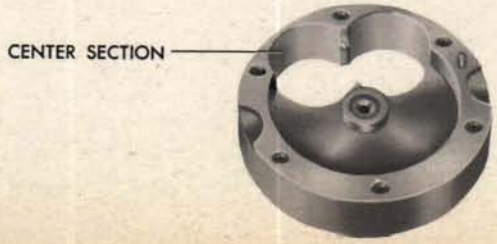
7 Lift out the right planetary gear. If it is not marked, tag it. The smaller hub of this gear faces upward.

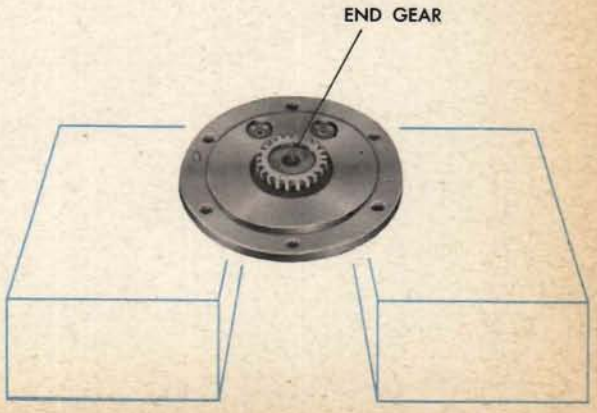
8 Lift out the left planetary gear. If it is not marked, tag it. The larger hub of this gear faces upward.



9 Remove the center section of the spider.

10 Remove the end gear from the cover.





PUNCH FOR JEWEL BEARINGS

PUNCH FOR REMOVING SHAFTS

PUNCH FOR INSTALLING SHAFTS

Repairing the parts

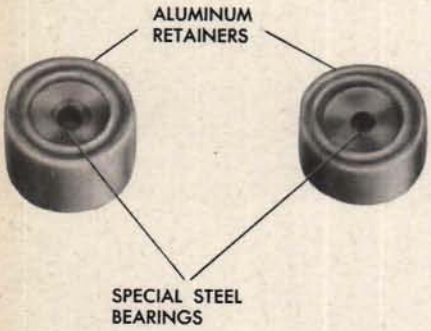
The repair procedure is the same for both the large and small jewel differentials.

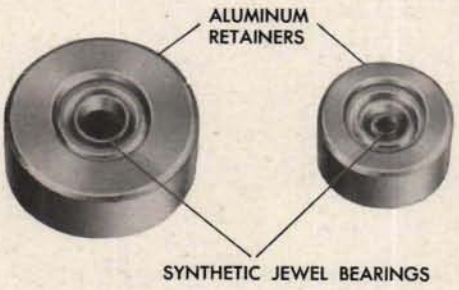
In shifting or removing a jewel bearing, use a punch that engages the aluminum retainer only and does not touch the jewel itself. In removing a shaft from a gear, use a hollow-pointed punch to fit the end of the shaft.

Shafting

To increase or decrease end play in a shaft, shift a jewel bearing. Use the special punch, and tap gently.

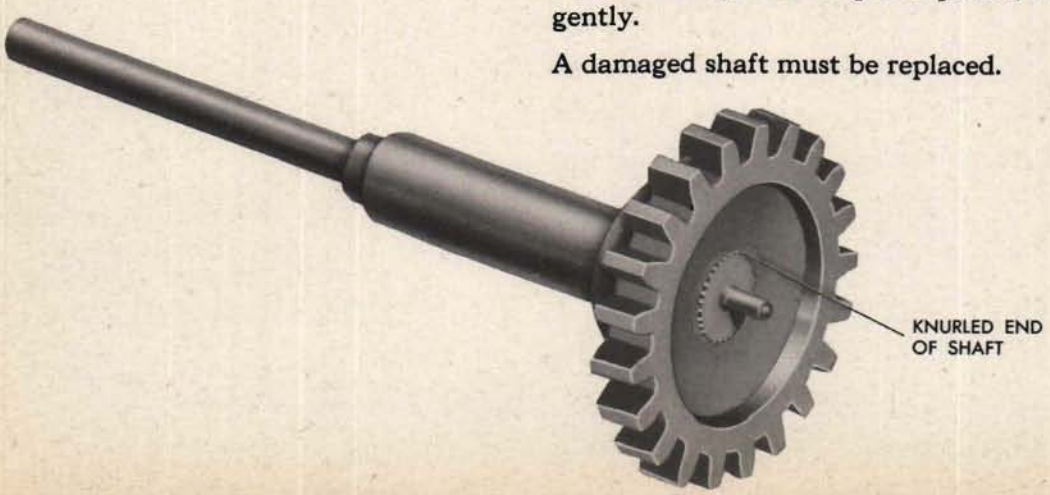
Polish a shaft that is burred, scarred, or fits too tightly in the bearing. Do not stone it.

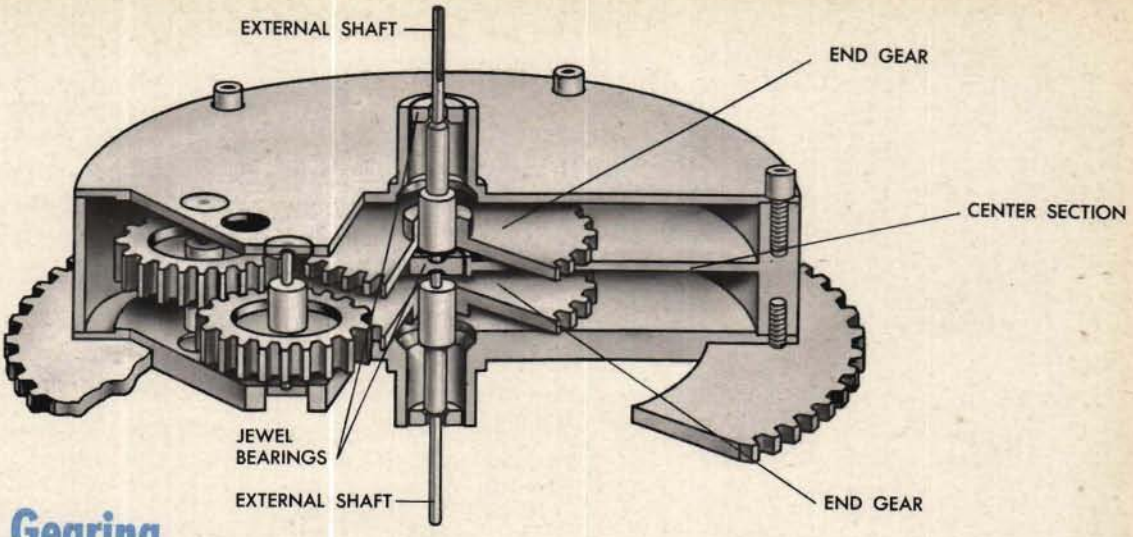




A damaged jewel bearing must be replaced. To avoid damaging a jewel when installing a new bearing, use the special punch, tapping gently.

A damaged shaft must be replaced.





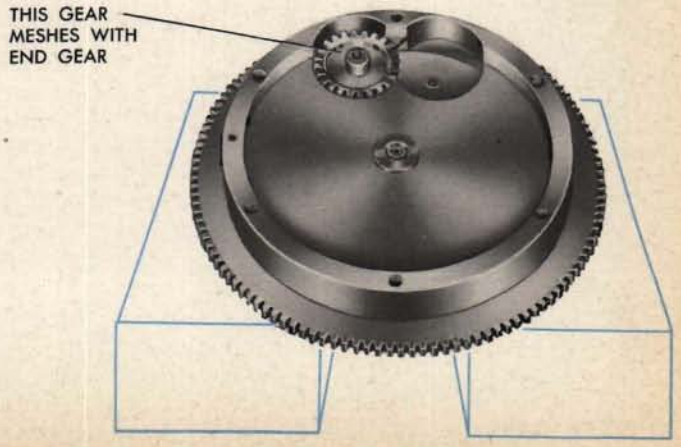
Gearing

If an end gear rubs on the surface of the center section, or on the side of the planetary gear with which it does not mesh, shift the jewel bearings of the external shafts to obtain the proper clearances.

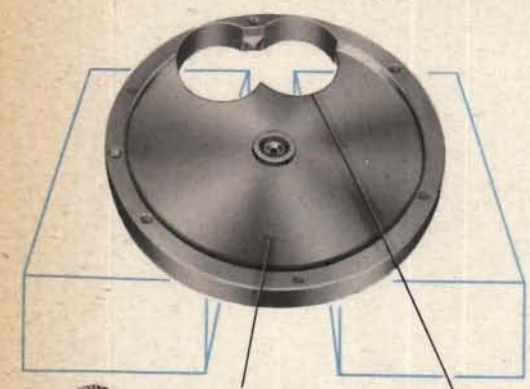
Replace any gear with excessively worn teeth, or a gear which slips on the knurled shaft. The shaft can be used again.

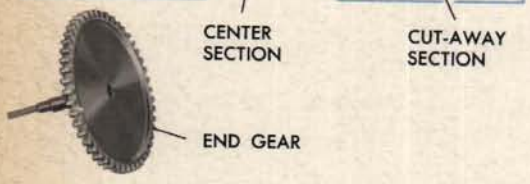
If a new gear is fitted on a shaft or a new shaft is fitted to an old gear, check the gear for run-out before installing it in the differential. See Basic Repair Operations, pages 68-71.

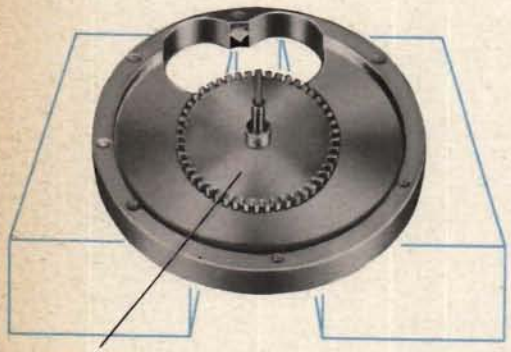
If the gears are clean and run true, but the mesh is tight, check the alignment of the cover plates to the center section. If a change is made, redoweling of the covers will be necessary. Refer to Basic Repair Operations, pages 74-75. If the mesh is still tight after redoweling, run-in two gears at a time by turning an external shaft and using a suitable running-in compound. Do not run-in the entire gearing at one time. Apply the compound carefully so that it does not enter the bearings.

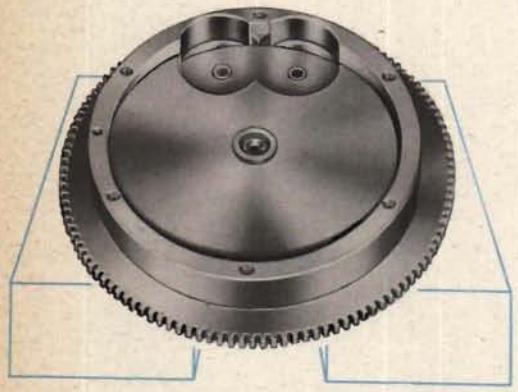


Reassembling the large jewel differential





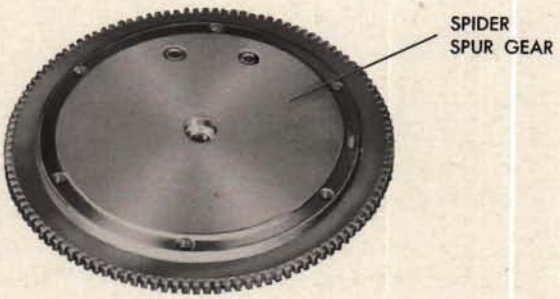




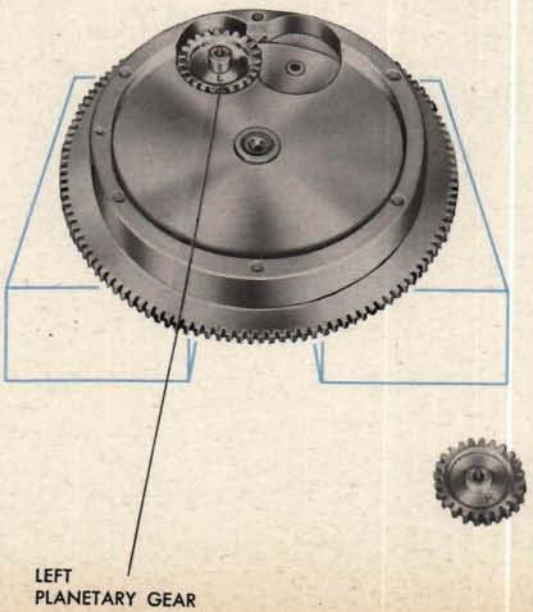
Use the assembly drawing as a guide for reassembly if it is available.

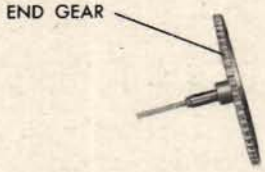
Wash all the parts with an approved solvent and dry them before beginning to reassemble the unit. Lubricate the jewel bearings with a half-drop of chronometer oil. Do not lubricate the gears. Check the mesh of each gear as it is mounted in the assembly.

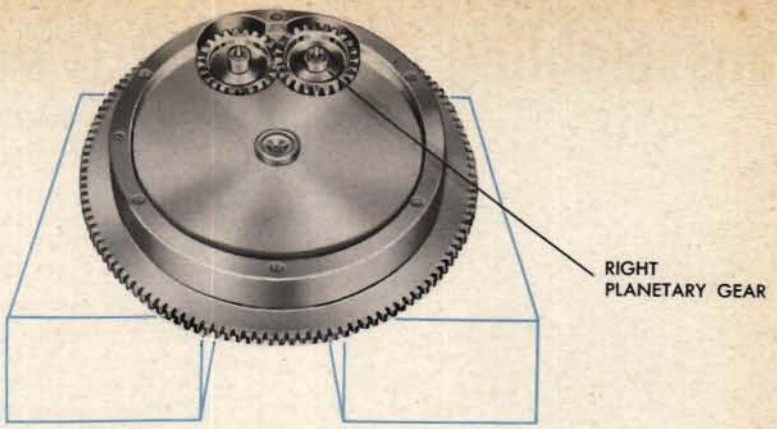
1. Support the center section on two blocks with the larger dowel hole upward and the cut-away section toward the back.
2. Mount the end gear which has the *short* flat on its shaft.



3. Mount the spider spur gear and secure it to the center section with the six long screws.
4. Invert the assembly.
5. Mount the left planetary gear with the larger hub upward.

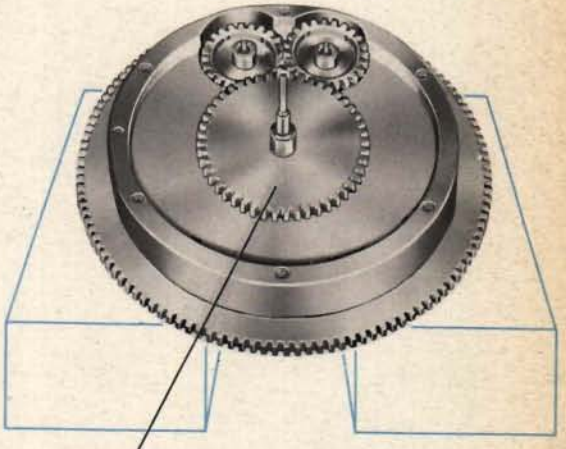


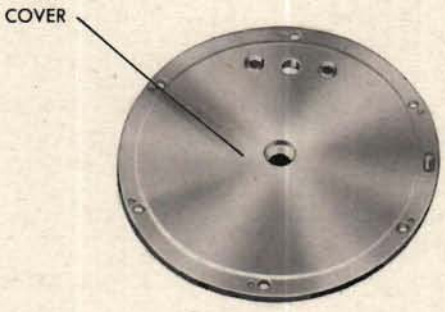




6 Mount the right planetary gear with the smaller hub upward.

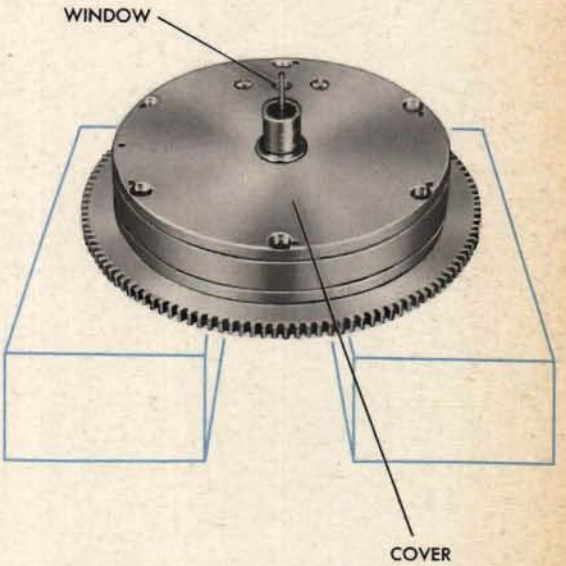
7 Mount the end gear.

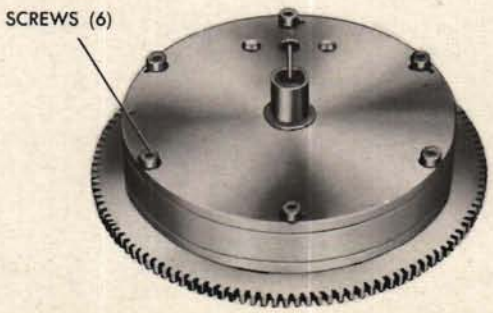




8 Put the cover in position but do not exert force to seat it. Before it can be fully seated, the planetary gear pivots must be located in their respective jewels. This can be done by working through the differential window with a pointed tool. While applying a light pressure to the cover, manipulate the gears until their pivots slip into the bearings, and then seat the cover.

9 Put the six screws in place and tighten them.

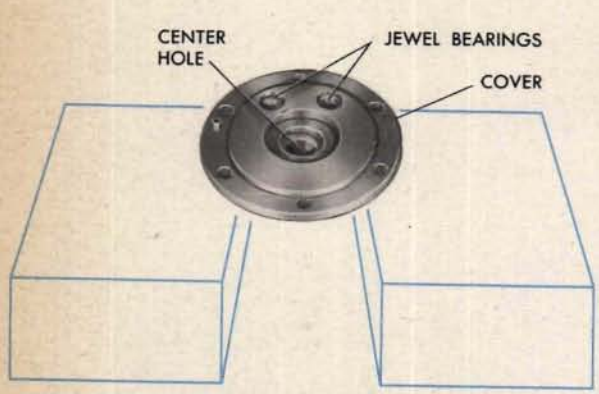




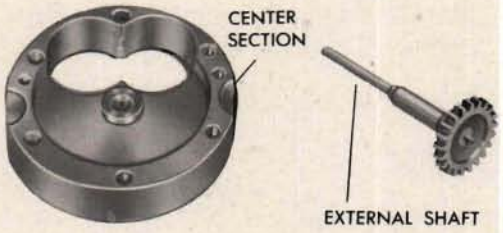
Reassembling the small jewel differential

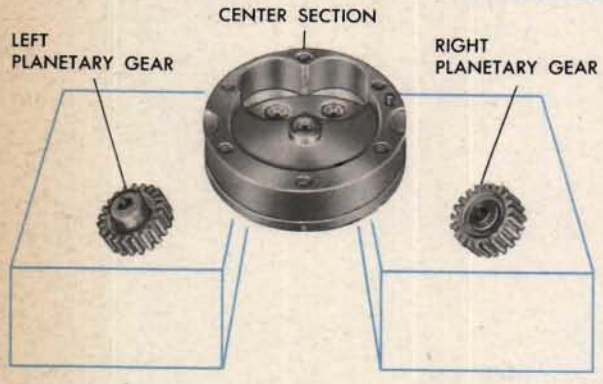
Always use the assembly drawing as a guide for reassembly.

Wash all the parts with an approved solvent and dry them before beginning to reassemble the unit. Lubricate the jewel bearings with a half-drop of chronometer oil. Do not lubricate the gears. Check the mesh of each gear as it is mounted in the assembly.



1 Support the cover on two blocks, with the two jewel bearings toward the back.





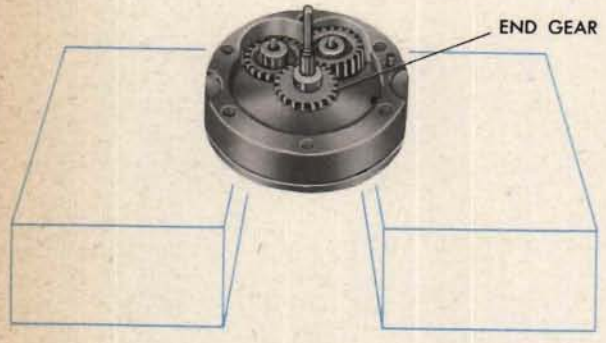
2 Mount the end gear with the longer shaft in the cover.

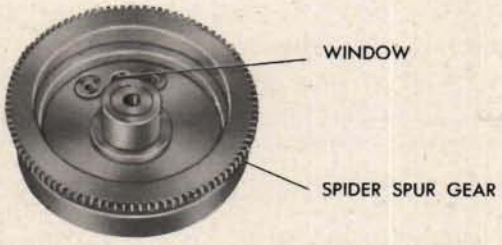
3 Mount the center section of the spider on the cover.

4 Mount the left planetary gear with its larger hub upward.

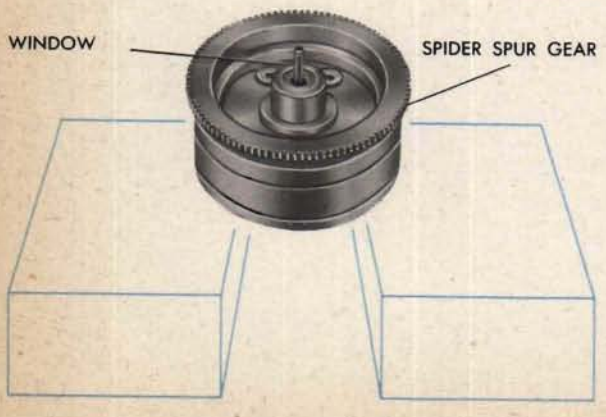
5 Mount the right planetary gear with its smaller hub upward.

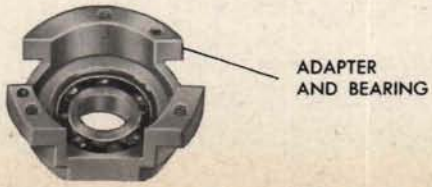
6 Mount the other end gear.

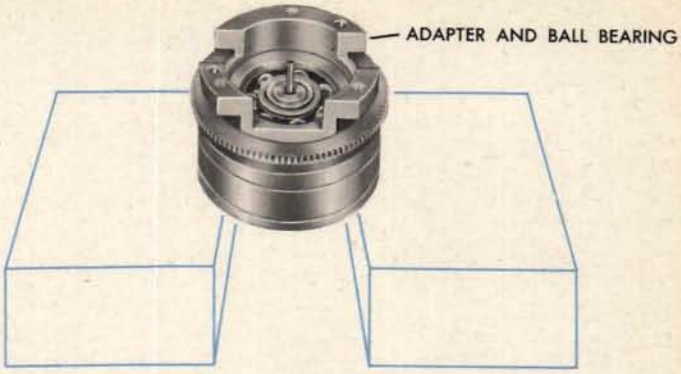




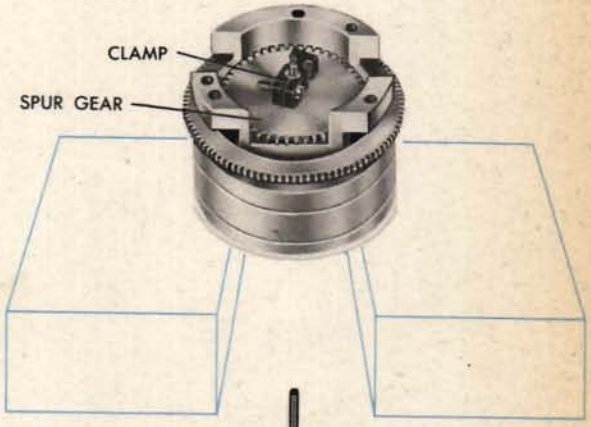
7 Put the spider spur gear in position on the center section but do not use force or attempt to seat it. Before the spider spur gear can be fully seated, the planetary gear pivots must be located in their respective jewels. This can be done by working through the differential window with a pointed tool. While applying a light pressure to the spider spur gear, manipulate the planetary gears until their pivots slip into the bearings.





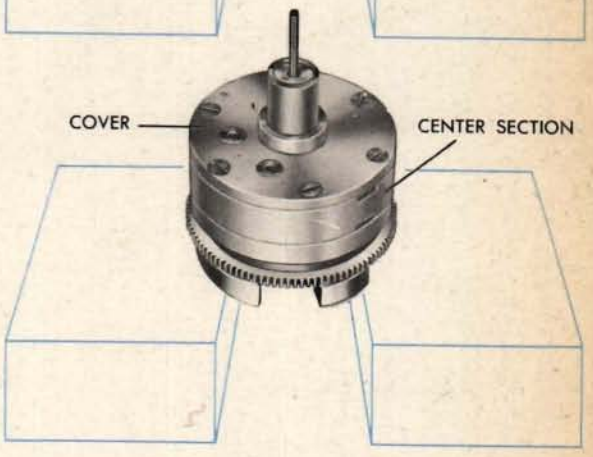


SPUR GEAR



8 Mount the adapter and ball bearing.
9 Mount the spur gear and clamp. Tighten the clamp.

10 Invert the differential. Put in and tighten the six screws.



Bench checking the unit

1 The differential must be very lightly lubricated at the pivots only. The gears must not be lubricated.

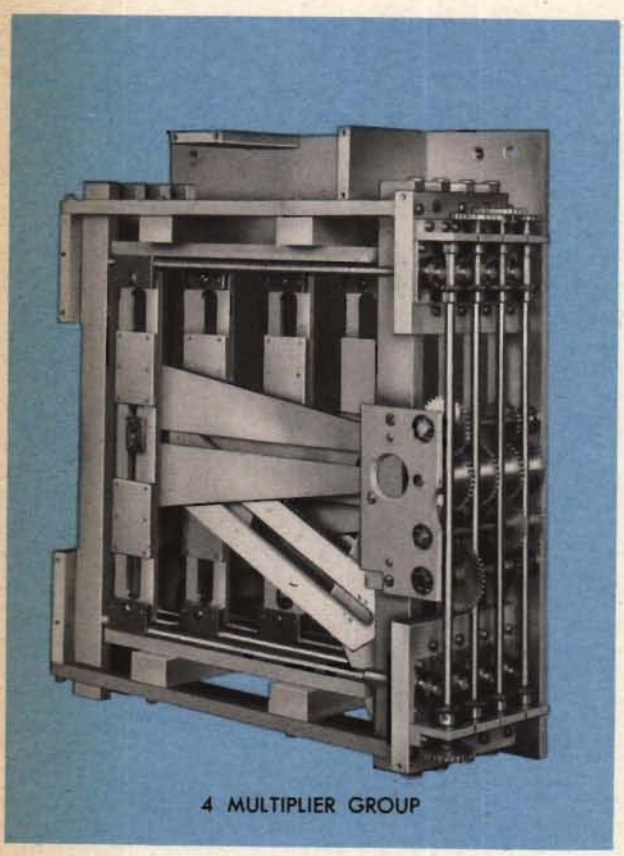
2 The spider spur gear must be clean and free of burrs.

3 The gear meshes must be free, yet have no lost motion.

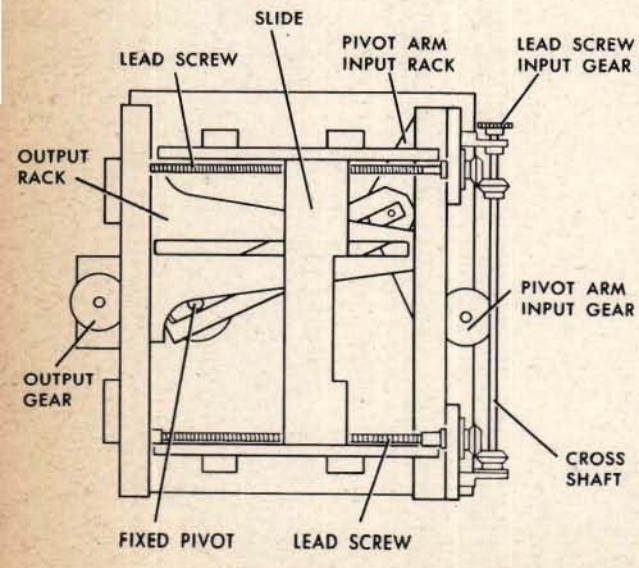
4 The shafts must have no more than 0.001 inch end play.

5 The internal gearing must turn smoothly and freely when a slight torque is applied to an external shaft.

THE SCREW TYPE MULTIPLIER



4 MULTIPLIER GROUP



Screw type multipliers are usually mounted side by side in groups of two, three, four, or more. A group of multipliers mounted in this manner forms one assembly. In such a multiplier group, the lead screw and pivot arm input gearing for all of the multipliers makes up one gearing group at one end of the assembly. At the opposite end, the output gearing of all of the multipliers makes up another gearing group.

In order to remove one multiplier, it is usually necessary to remove the input and output gearing groups. Before the gearing groups are removed, however, the trouble must be exactly located in one multiplier. If the unit must be removed for repair, consult the instrument OP for instructions.

Typical symptoms

If a test analysis and unit check tests have indicated that a screw type multiplier is not operating normally, look for the following typical symptoms:

LEAD SCREW INPUT – JAMMING or STICKING: The lead screw input gear cannot be turned by hand, resists turning past a certain point or points, or turns sluggishly.

LEAD SCREW INPUT – EXCESSIVE LOST MOTION: There is too great a lag between the turning of the lead screw input gear and the movement of the traveling slide.

LEAD SCREW INPUT–SLIPPING: Turning the lead screw input moves the traveling slide only intermittently.

RACKS – JAMMING or STICKING: The input rack cannot be moved by hand, resists moving past a certain point or points, or moves sluggishly.

RACKS – EXCESSIVE LOST MOTION: There is too great a lag between the moving of the input rack and the moving of the output rack.

RACKS – SLIPPING: Moving the input rack does not move the output rack.

Locating the cause

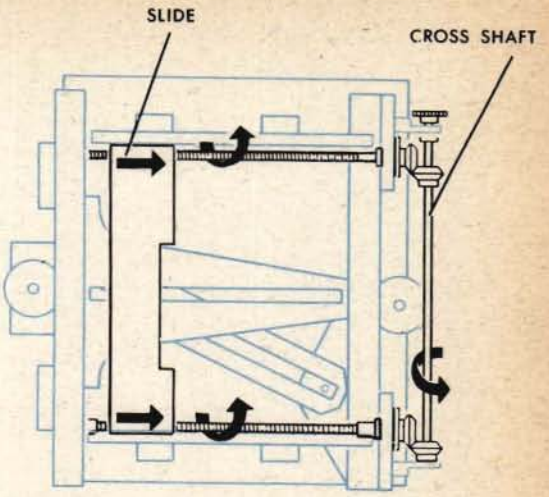
Lead screw input: jamming or sticking

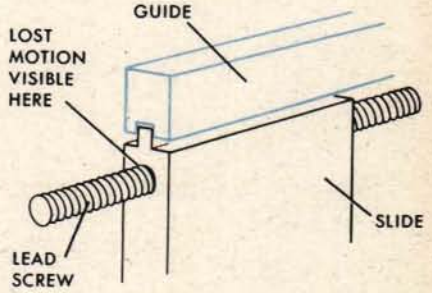
The lead screw input may resist turning because the slide is jammed against the limit of its travel. If the sticking or jamming occurs when the slide is somewhere between the limits of travel, the source of trouble may be a bent lead screw, dirty or damaged lead screw threads, or dirty or damaged guides. Also, the lead screw input may jam or stick because of dirty or damaged gears or bearings in the input gearing, or because of slide blocks sticking in the rack slots.

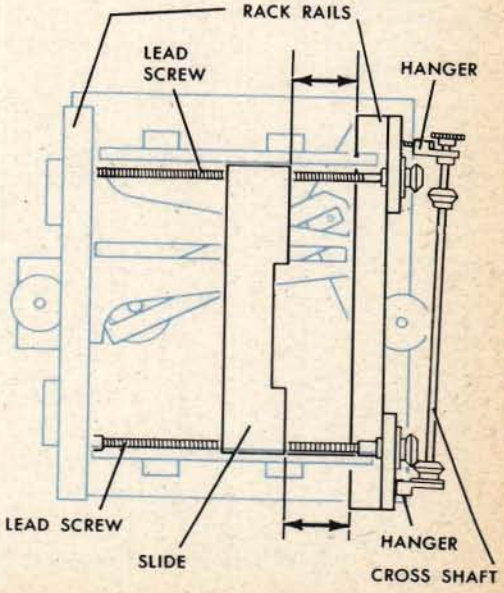
If the lead screw has jammed the slide against the limit of its travel, it can usually be backed out by hand. Try to move it by turning the lead screw input gear. After it comes free, run the slide through its full travel to be sure that the lead screw threads are undamaged. Jamming of the slide into one of its limits is the result of an incorrect limit stop adjustment. Directions for readjusting the limit stop are given in the instrument OP.

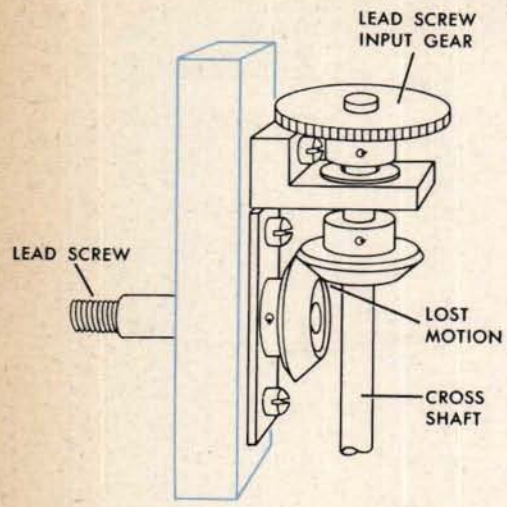
If the slide sticks or jams at some point within its normal travel, examine the lead screw threads and the guides for damage. Check the freedom of the lead screw in the slide and the slide in the guides. Even though these parts are made so that they fit very snugly, there should be a little lost motion. Absence of lost motion points to the location of the source of sticking or jamming. A damaged guide or a slightly damaged lead screw usually can be repaired, but a badly damaged or bent lead screw should be replaced.

If the slide sticks all along its travel, the slide may be askew. A loose cross-shaft hanger may have permitted one of the bevel gears on the cross shaft to slip with respect to its mating gear on the lead screw. In order to correct this condition, unmesh one pair of bevel gears and turn one of the lead screws until the slide is parallel to the rack rails. Remesh the gears and secure the hanger in place.





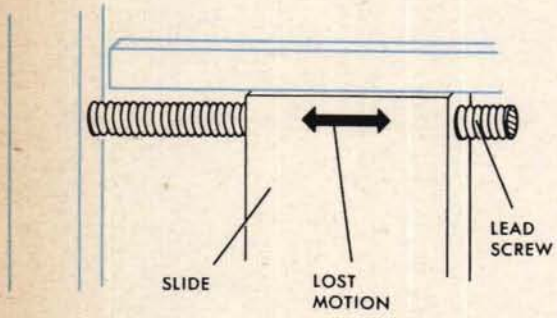




Lead screw input: excessive lost motion

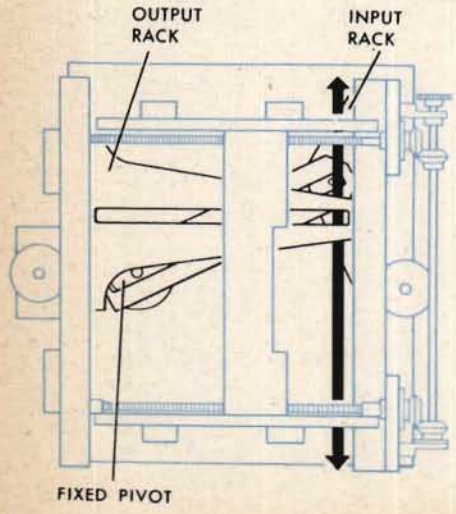
Excessive lost motion may be the result of worn bevel gear teeth, lead screw threads, or excessive end play of either the lead screw or the cross shaft.

Inspect the parts to locate the points of wear. The combined lost motion of the slide and the end play of the lead screw should be less than 0.0015 inch. Therefore, if the lost motion between the slide and one of the screws approaches this figure, replace the screw. Usually, lost motion between the bevel gears—which should average 0.001 inch—and end play of the cross-shaft or a lead screw can be eliminated by shifting hangers and changing spacers. Follow the method given in the chapter on *Shaft Lines*.



Lead screw input: slipping

Slipping may be the result of a sheared or missing taper pin in the bevel gears or of stripped lead screw threads. Replace a missing taper pin. The other casualties mentioned usually mean deformed or broken parts which should be replaced.

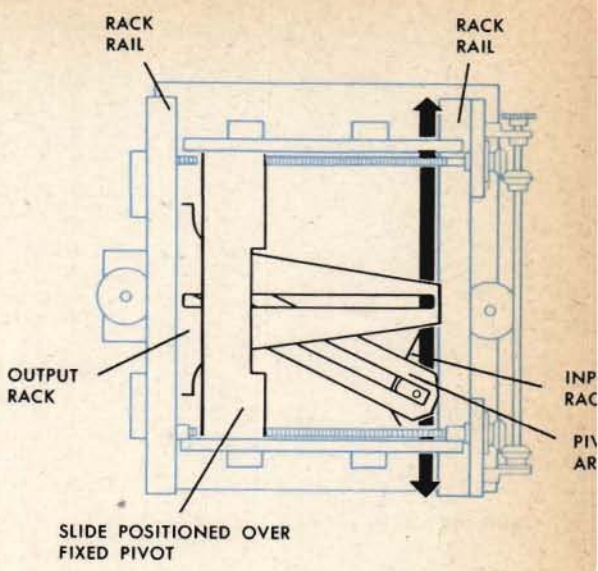


Racks: jamming or sticking

Move the input rack through its full travel and check the smoothness of operation. If the input rack jams, or if any sticks are felt, the trouble may be in either the input or the output rack.

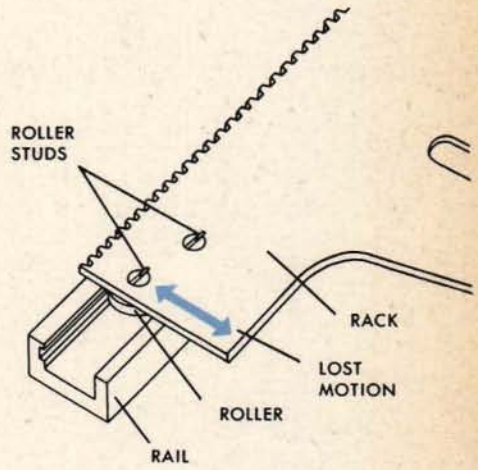
Position the slide over the fixed pivot so that there is no motion of the output rack when the input rack is moved. Now, if the input rack travels smoothly and freely, the trouble probably is in the output rack or its related parts. The source of trouble may be dirty or damaged output rack rollers, bent roller studs, a dirty or damaged roller path in the rack rail, or a tight mesh between the output rack and the output gear. However, if there is no trouble in the output rack, then the slide block may be jamming or sticking in its slot in the slide.

If when the multiplier stud is over the fixed pivot, the input rack jams or sticks, the trouble is in the input rack or its related parts. The source of trouble may be where the pivot arm pivots on the input rack, on the multiplier stud, or on the fixed pivot; as well as dirty or damaged input rack rollers and roller studs, a dirty or damaged roller path, or a tight input gear mesh.



Racks: excessive lost motion

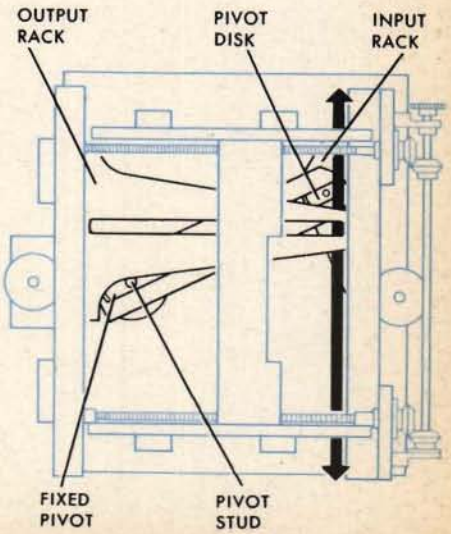
Excessive lost motion between the slide, the input rack, and the output rack may be caused either by bent or loose roller studs or by a worn slot. Loose roller studs can be tightened by riveting and the rollers adjusted in order to reduce lost motion. Bent studs and parts with worn slots cannot be repaired; they should be replaced.

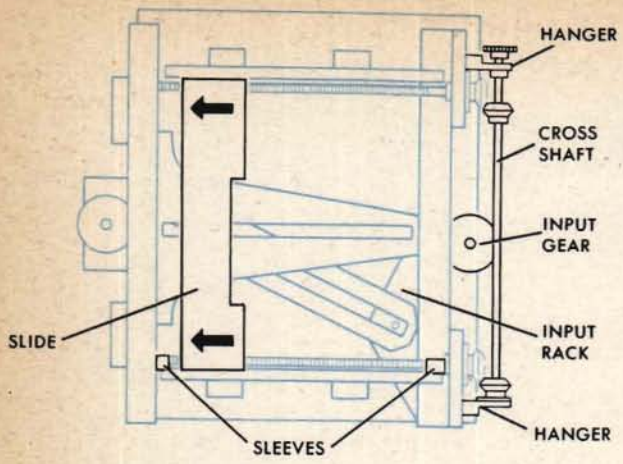


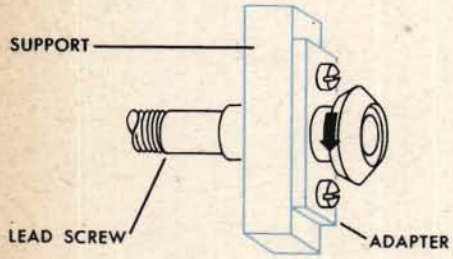
Racks: slipping

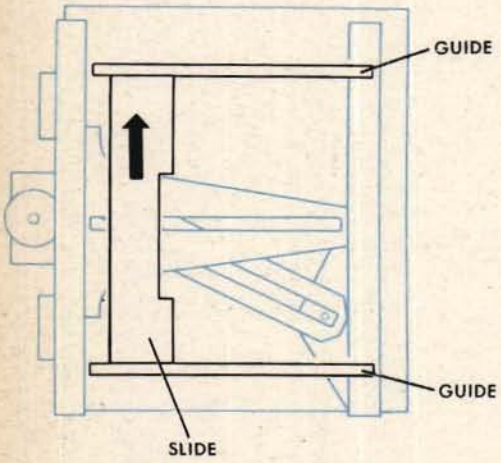
When the slide is not positioned over the fixed pivot; if moving the input rack does not move the output rack, a pivot stud is broken.

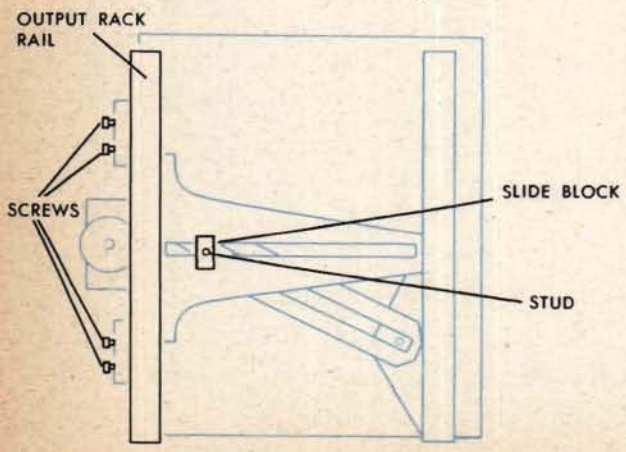
To install a new pivot stud, the multiplier should be removed from the instrument.











Disassembling the unit

For the sake of clarity, most of the following illustrations were drawn with only the top multiplier visible.

1 Move the slide away from the cross shaft to the limit of its travel.

2 Remove the input gear meshing with the input rack.

3 Remove the cross shaft assembly by taking out the hanger screws.

4 Remove the screws securing the lead screw adapters.

5 Turn the lead screws to back them out of the slide and to push the adapters out of their supports. Tag the two sleeves noting their positions on the lower lead screw.

CAUTION:
The adapters are doweled. Do not forcibly "jack" one off with the lead screw because damage to the lead screw may result. If an adapter does not come off easily, use a thin, sharp wedge to start it off the dowels.

6 To remove the slide, first remove the guides. Then pull the slide off its block by moving it in the direction shown by the arrow.

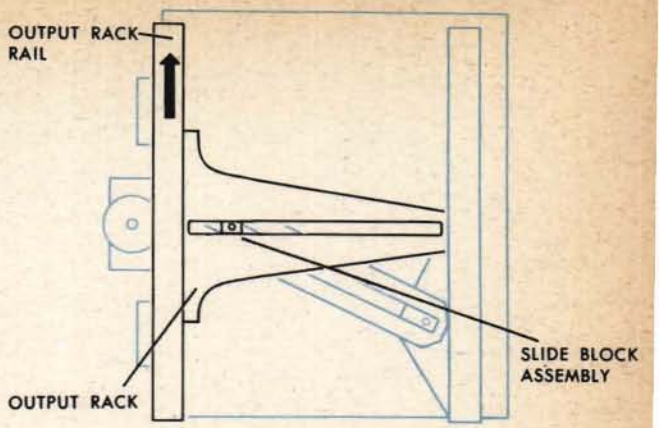
7 Remove the slide block and, for safe keeping, replace it in the slide just removed.

8 Remove the screws holding the output rack rail.

9 Slide off the output rack rail.

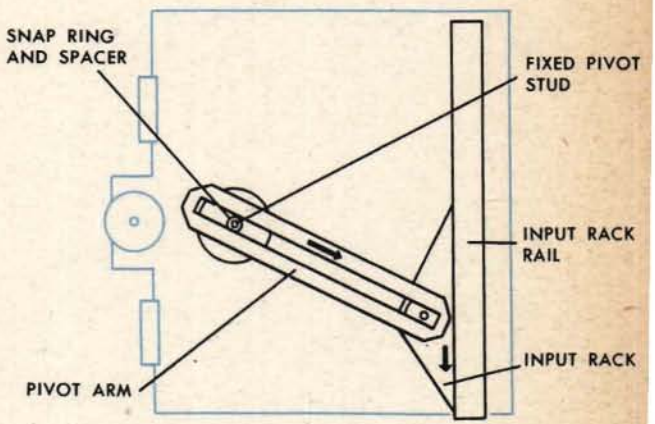
10 Lift off the output rack.

11 Note the way the slide block assembly is mounted in the input and output rack slots. Lift the blocks out.



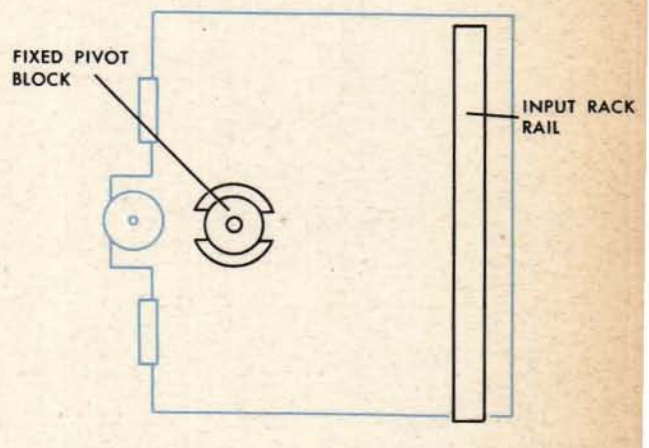
12 Remove the snap ring and spacer from the fixed pivot stud.

13 Slide the input rack off the end of its rail. The pivot arm will slide out of the pivot block if the pivot block is raised slightly so that the arm will clear the stud.

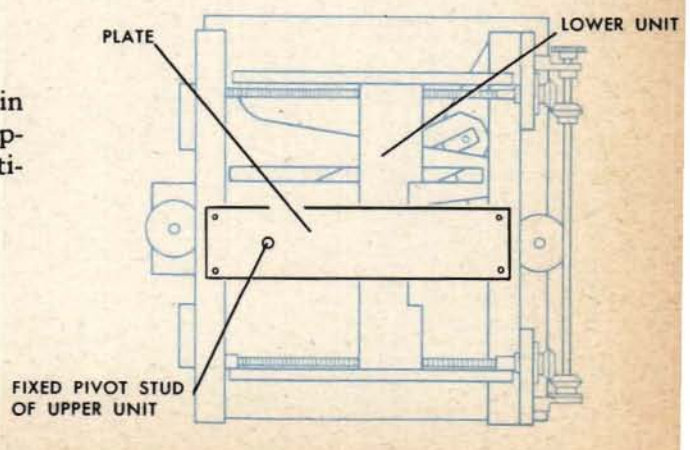


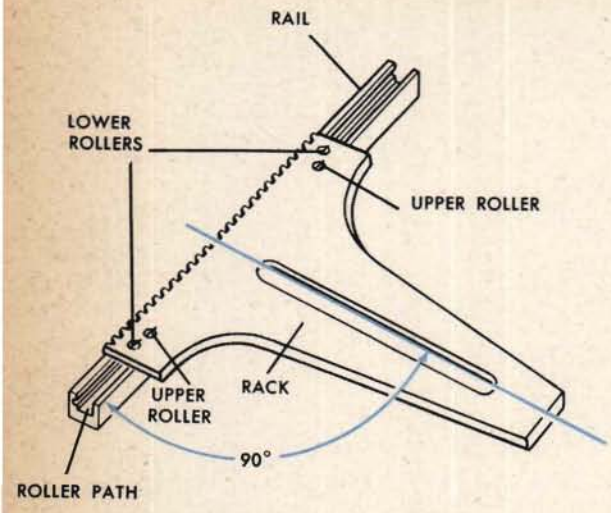
14 Lift off the fixed pivot block.

15 Remove the screws holding the input rack rail and lift off the rail.



16 To disassemble the next multiplier in the group, remove the plate which supports the fixed pivot stud of the multiplier just disassembled.

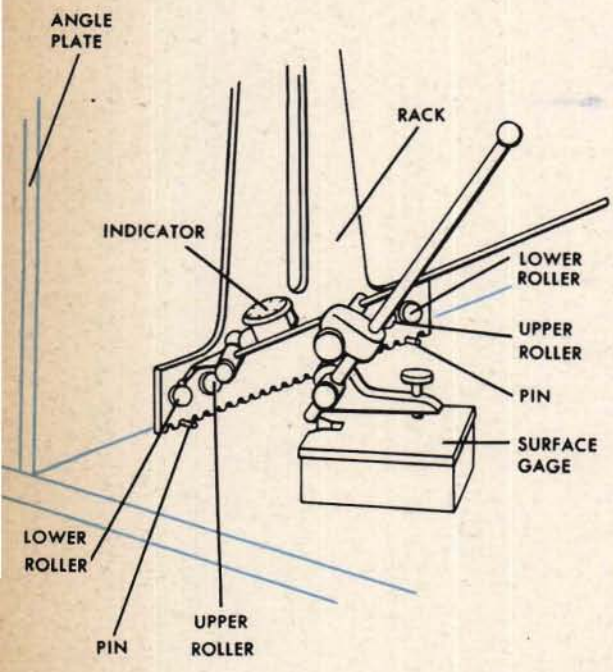




Repairing the parts

Repairing a rail

First clean the roller path in the rail, and look carefully for embedded foreign materials. Polish any rough or high spots, and try the rack in the rail frequently until a good fit is obtained. After completing this work, wash all parts thoroughly with an approved solvent.

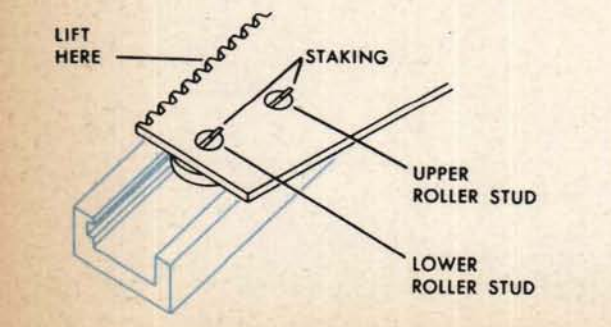


Adjusting the rollers

The lower rollers establish the pitch line of the rack in relation to its meshing gear. These rollers also affect the squareness of the rack to the rail. Remove the rack and mount it against an angle plate on a surface plate. Support the rack under the teeth, using two identical pins between 0.070 inch and 0.075 inch in diameter. Place a pin at each end of the rack.

With a surface gage and a dial indicator, measure the height of the lower rollers. The heights of these rollers must agree with the assembly drawing and be within 0.0002 inch of each other.

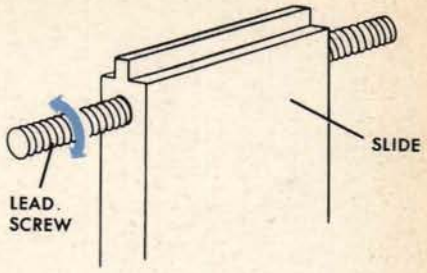
The upper rollers control the play between the rack and the rail. If the play exceeds 0.0005 inch, turn the roller studs with a screw driver. A strip of feeler-gage material (0.001 inch) can be used as a "not go" gage to check the clearance between the roller and the roller path. After positioning the rollers, stake a small amount of metal into the screw-driver slots of the stud heads. The rollers should be free enough in the rail for the rack to drop back of its own weight if it is raised slightly with one finger.



For an explanation of removing and replacing a riveted stud, see pages 76-79.

Fitting a new lead screw

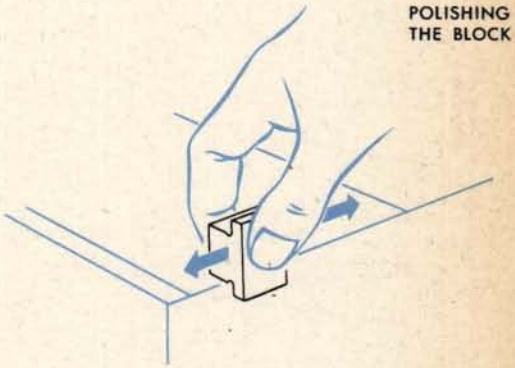
Inspect the threads of a new lead screw for dirt or damage. Grease the lead screw and turn it carefully into the threaded hole in the slide. Do not force the lead screw. Turn it into the threaded hole along its full length and then back it out to check smoothness of operation. Remove the lead screw before fitting the bearings and the bevel gear. Then wash all parts thoroughly in an approved solvent.



Fitting a new slide block

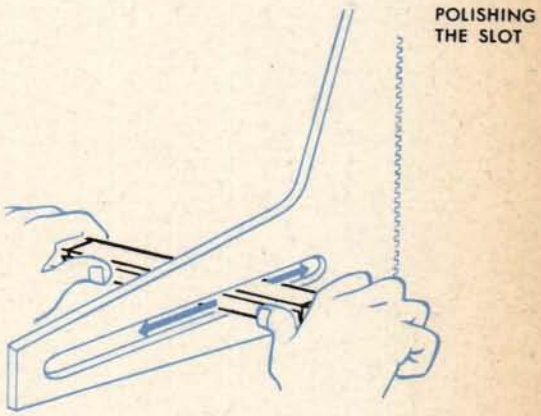
Use a fine oilstone to smooth burred or rough edges of a new block. Remove any extremely sharp edges, but leave the block square. It is very important not to round or chamfer the edges.

To reduce the width of a block, polish the sides on a piece of crocus cloth placed on a flat surface. Use long, even strokes while holding the block square. Be sure to remove equal amounts from both sides so that the hole remains centered. Measure the block occasionally with a micrometer to be certain that the sides are parallel.



Polish the block until it fits the widest portion of the slot without lost motion. Using crocus cloth over a steel bar, polish the rest of the slot to fit the block. Be sure to keep the slot sides square and flat.

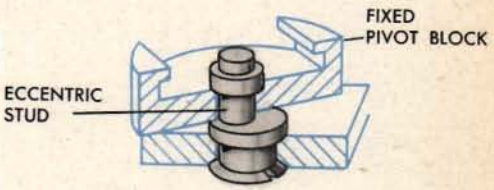
Remove the block from the slot, clean both parts thoroughly, and lubricate them. Fit the block into the slot and move it back and forth until it travels smoothly along the entire length of the slot.

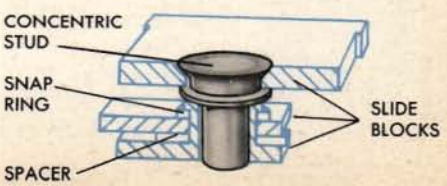


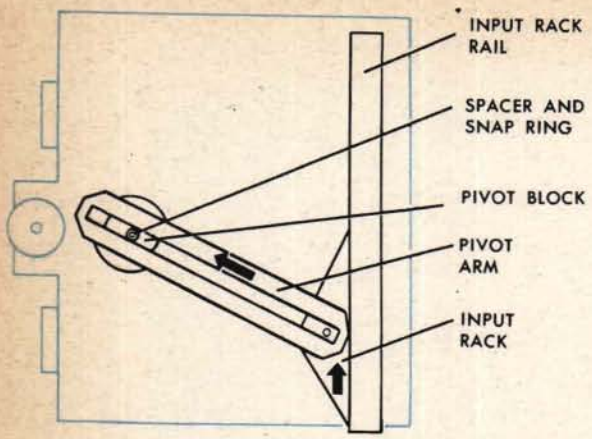
Replacing a pivot stud

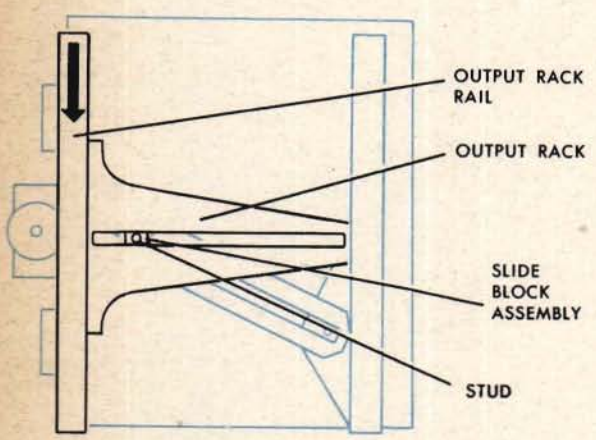
Following the instructions on riveting, pages 76-79, drill out and replace the stud. The fixed pivot stud is eccentric. Consult the assembly drawing and adjust the stud at the indicated distance from the multiplier pivot disk.

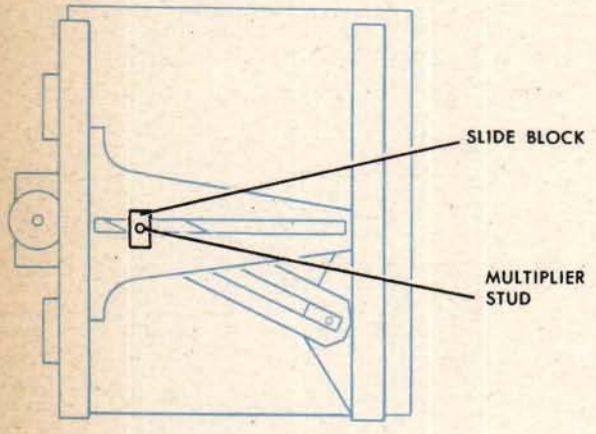
The multiplier stud in the slide is concentric and does not require adjustment.

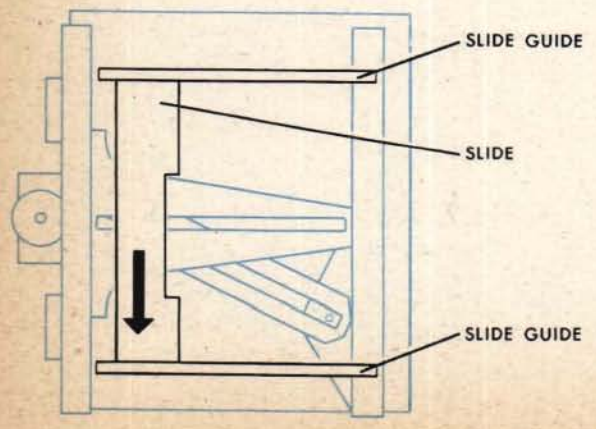












Reassembling the unit

Wash all the parts with an approved solvent and dry them before starting to reassemble the unit. Lubricate each part before replacing it. After mounting each part, check the operation of all parts for smoothness and proper lost motion.

If the multiplier is to be assembled on top of another multiplier, first replace the plate which supports the fixed pivot stud.

1 Replace the input rack rail.

2 Replace the pivot block on the stud

3 Raise the pivot block slightly, and slide the pivot arm into it. At the same time, slide the input rack onto its rail.

4 Replace the spacer and snap ring.

5 Replace the slide block assembly in the pivot arm slot. Be sure that the blocks are in the order indicated on the assembly drawing.

6 Put the output rack in position. Slide the output rack rail on the output rack rollers, and secure it in place. The mesh between the output rack and output gear should be free, yet have minimum lost motion.

7 Insert the multiplier stud in the slide block assembly.

8 Push the slide onto its block.

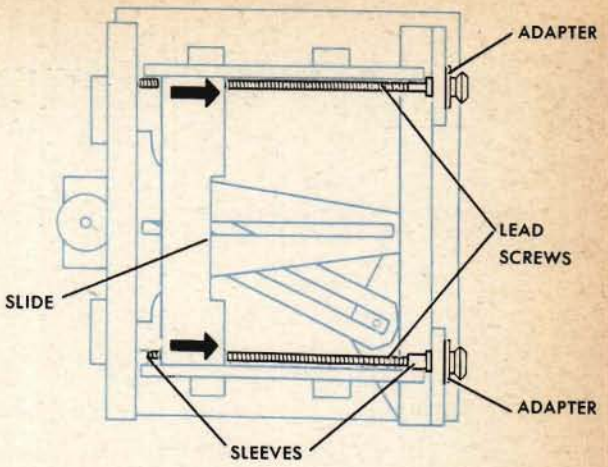
9 Replace the slide guides.

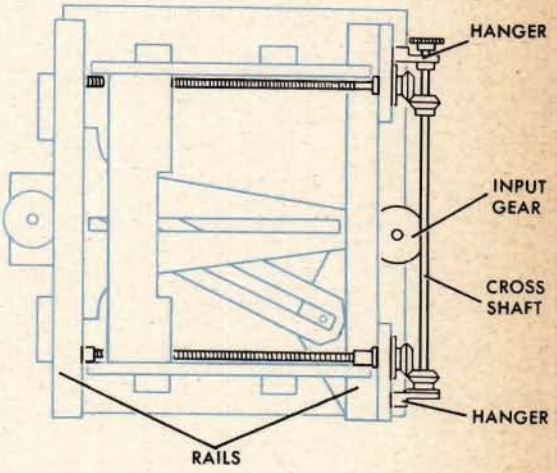
10 Insert the lead screws through the holes in the adapter supports. Replace the long sleeve on the lower lead screw. As there are four threads on each lead screw, start the lead screw into the slide in different positions until the one with the smoothest rotation is found. Replace the short sleeve on the lower lead screw.

11 Insert the ends of both lead screws into the holes in the input rack rail; then secure the adapters in their supports.

12 Replace the cross shaft, making the gear meshes so that the slide is parallel to the rack rails. Refer to the assembly drawing for the tolerances. Position the cross-shaft hangers for the minimum amount of shaft end play and lost motion.

13 Replace the input gear. Its mesh with the input rack should be free, yet have minimum lost motion.





Bench checking the unit

1 Check the assembly of the multiplier against the assembly drawings.

2 All gears should mesh freely with less than 0.001 inch lost motion.

3 The lead screw should be free to turn through the entire travel of the slide.

4 The combined end play of the lead screw and the slide should not exceed 0.0015 inch.

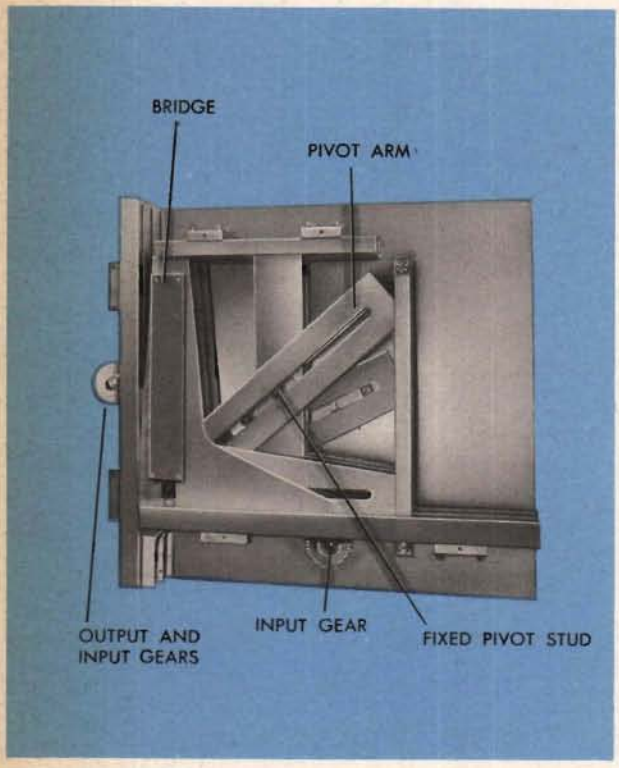
5 The racks should mesh properly with their gears throughout their entire travel.

6 All eccentric studs in the racks and bridges should have been staked.

7 Lost motion between the input and output racks and the slide should be at a minimum. Refer to the assembly drawing.

8 Make sure that the rails and the traveling slide are parallel. Place the slide at one end of its travel. Moving the input rack through its entire travel should not move the block in the output rack.

THE RACK TYPE MULTIPLIER



A rack multiplier is usually mounted on a base plate with gearing groups and other units. Occasionally one may be mounted on a separate base plate. It can seldom be disassembled in the instrument because other units near by do not allow enough space. For instructions on removing the unit from the instrument, consult the instrument OP.

The rack type multiplier has two input racks and one output rack. One input rack has a slot covered by a plate referred to as a bridge. The other input rack is joined to a pivoted arm. The output rack is between the two input racks.

Typical symptoms

If a test analysis and unit check test indicate that a rack multiplier is not operating normally, look for one of the following typical symptoms:

JAMMING: One or more racks will not move at all.

STICKING: One or more racks resist moving past a certain point or points, or move sluggishly.

EXCESSIVE LOST MOTION: There is too much play between the input and output racks.

SLIPPING: Moving the input rack moves the output rack only intermittently, or not at all.

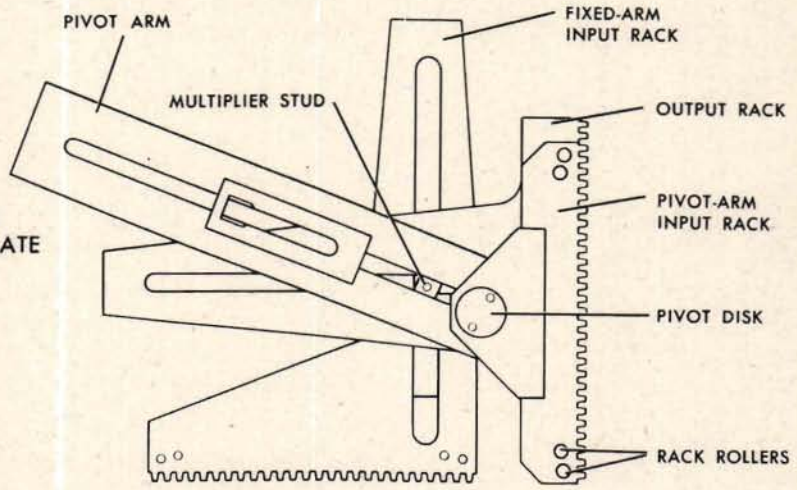
Locating the cause

Jamming

Try to move the pivot-arm input rack through its full travel. If it will not move, try to move the fixed-arm input rack. If neither input rack can be moved, the slide blocks may be binding in their slots.

If only the fixed-arm input rack can be moved, the block in the pivot arm slot may be frozen on the fixed pivot stud, the multiplier stud may be frozen in its slide blocks, the pivot disk in the pivot-arm input rack may be frozen, or the rollers on the pivot-arm input rack may be binding in their rail.

If the fixed-arm input rack is jammed when the pivot-arm input rack is held but is free to move when the pivot-arm input rack is free to move, the output rack rollers are probably jammed in their rail.



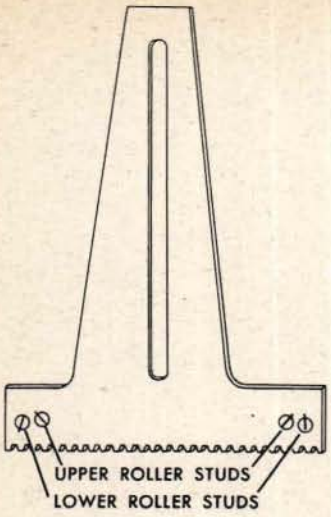
POSITION OF RACKS AS VIEWED FROM PLATE

Sticking

The same methods that are used to locate the causes for jammed racks may be used when the racks stick.

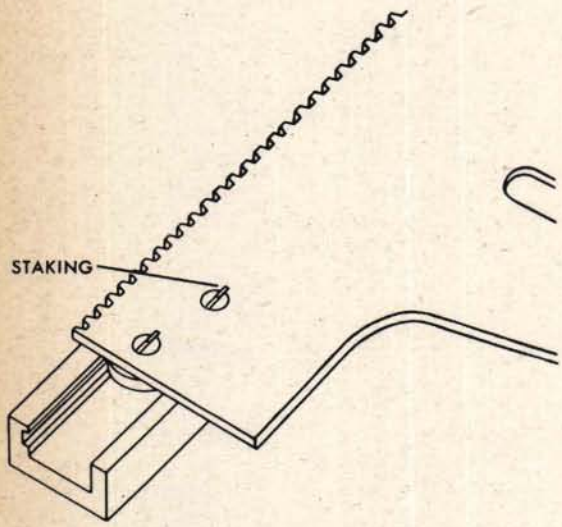
Shake the racks to check for lost motion on the rails. Incorrect adjustment between the rack rollers and the rack may cause a tight mesh between the rack and its meshing gear. The racks may also stick because of dirty or damaged teeth in the rack or gear.

Disassemble the unit for repair only if the racks stick enough to cause serious errors in the operation of the instrument. Slight sticking in the rack slots can be eliminated by cleaning the sliding surfaces. Then lubricate the unit and run the sticking parts back and forth by hand.

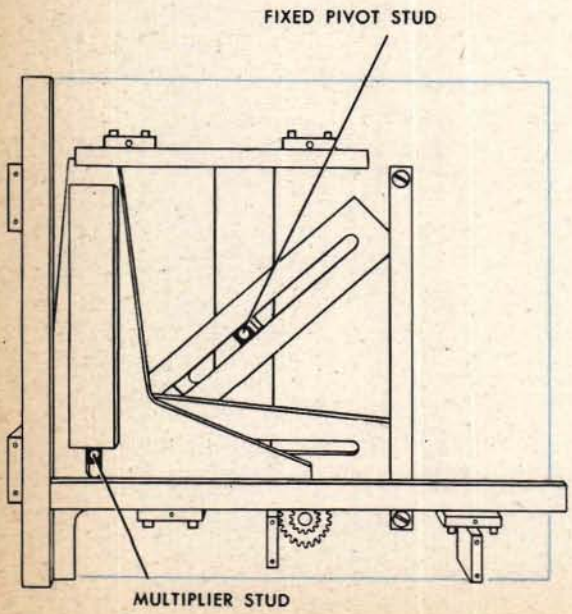


Excessive lost motion

Shake each rack to check lost motion between the rack and its rail. If the lost motion exceeds the allowable limits given on the assembly drawing, adjust the upper roller studs.



Check for lost motion between the input and output racks by holding the output rack; then position the fixed-arm input rack at different points along its travel and shake the pivot-arm input rack. Excessive lost motion here may be caused by worn slide blocks or rack slots. The unit must be disassembled and the worn parts replaced.



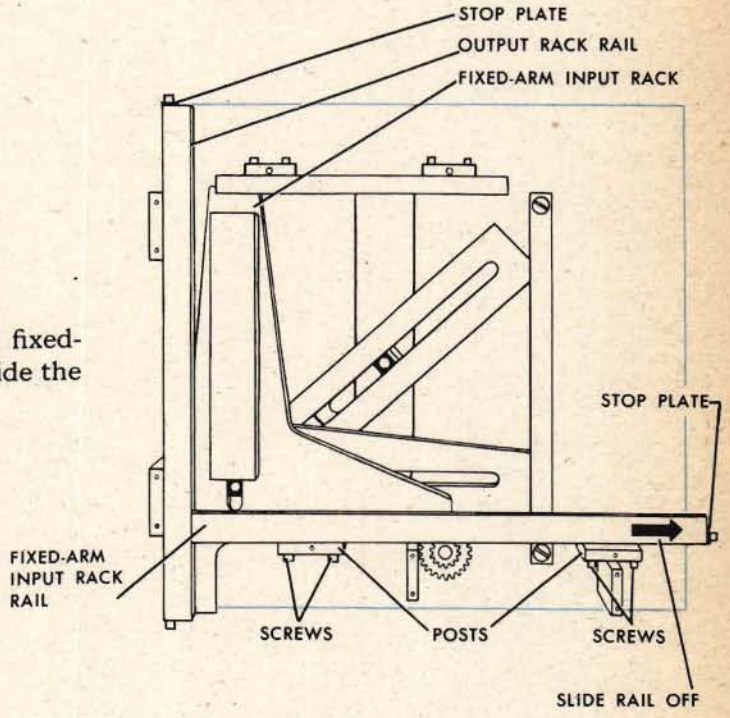
Slipping

Slipping may be caused by broken pivot studs. Check for a sheared pivot stud by placing one input rack at one end of its travel; then move the other input rack through its travel. Carefully observe the output rack to see whether it moves smoothly. If it does not, either the fixed pivot stud or the multiplier stud in the slide has been sheared or loosened. Repair requires disassembly of the unit.

Disassembling the unit

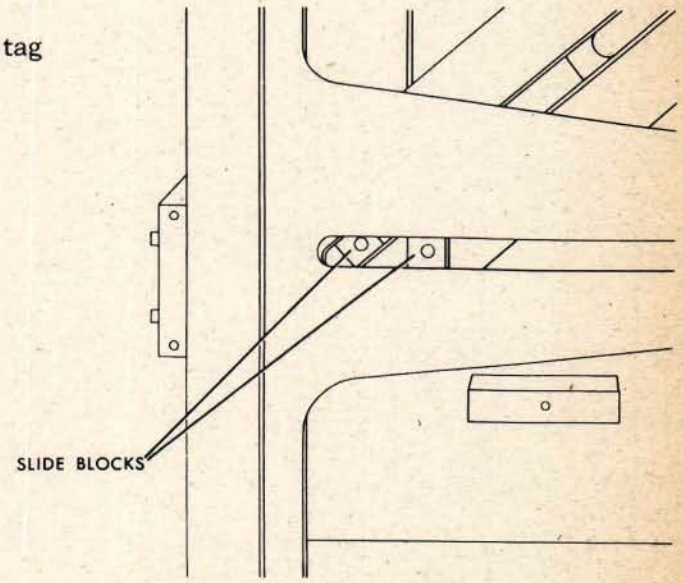
1 Remove the two stop plates. Remove the screw at the bottom of the output rack rail.

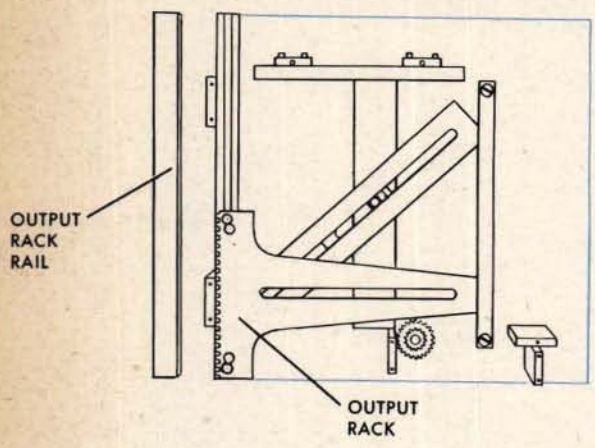
2 Take out the screws holding the fixed-arm input rack rail to the posts. Slide the rail off the rollers.



3 Lift off the fixed-arm input rack.

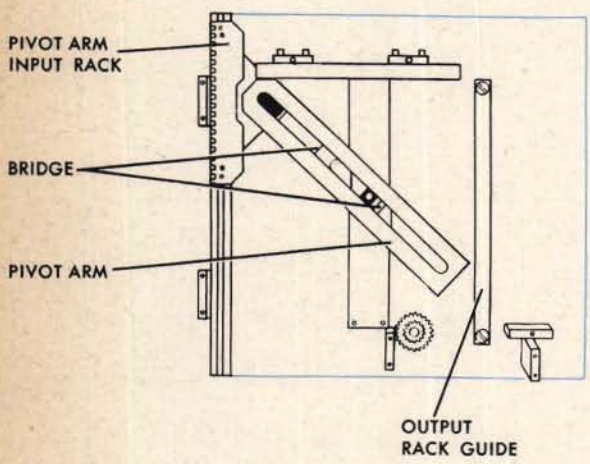
4 Lift out the two slide blocks and tag them.



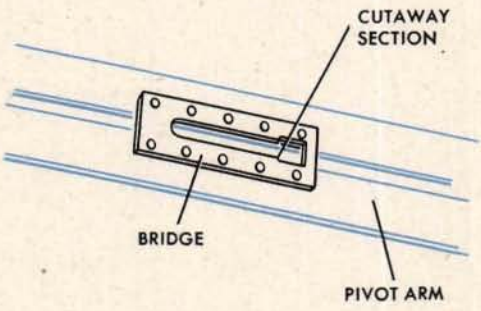


5 Remove the output rack rail.

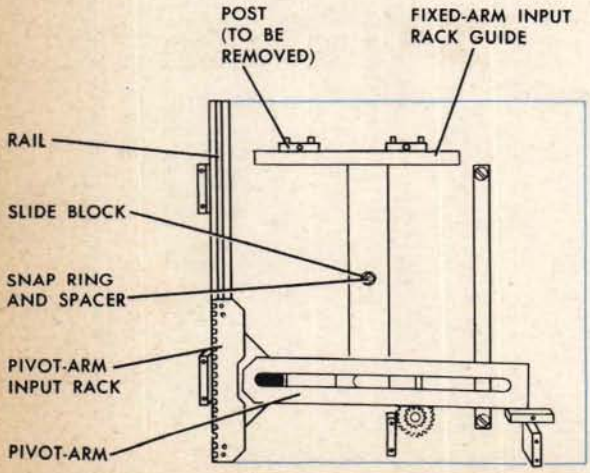
6 Take off the output rack.



7 Move the pivot-arm input rack so that the slide block is in the cutaway section of the bridge. Raise the arm off the block.



UNDERSIDE OF PIVOT ARM



8 Remove the snap ring and spacer from the fixed pivot stud.

9 Remove the slide block from the fixed pivot stud.

10 Remove the fixed-arm input rack guide.

11 Remove the post indicated in the illustration.

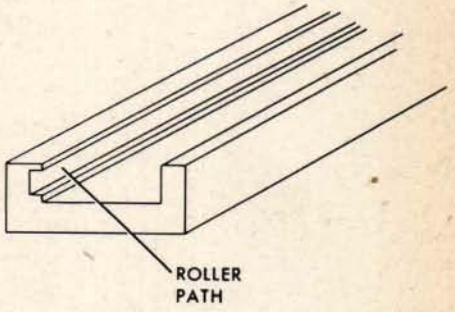
12 Run the pivot-arm input rack up, out of the rail.

13 Remove the plate holding the fixed pivot stud.

Repairing the parts

Repairing the input and output rails

Clean the roller paths with an approved solvent, and examine them carefully for embedded foreign matter. Polish any rough or high spots by stroking the roller paths with a square steel bar wrapped in crocus cloth. Run the rack in the rail frequently until a good fit is obtained. Then clean and lubricate the parts thoroughly.



Adjusting the rollers

The lower rollers establish the pitch line of the rack in relation to its meshing gear. These rollers affect the alignment of the rack slots as well as the mesh of the rack and the gear. Remove the rack and mount it against an angle plate on a surface plate. Support the rack under the teeth, using two identical pins between 0.070 inch and 0.075 inch in diameter. Place a pin at each end of the rack.

With a surface gage and a dial indicator, measure the height of the lower rollers. The heights of these rollers must agree with the assembly drawing and be within 0.0002 inch of each other.

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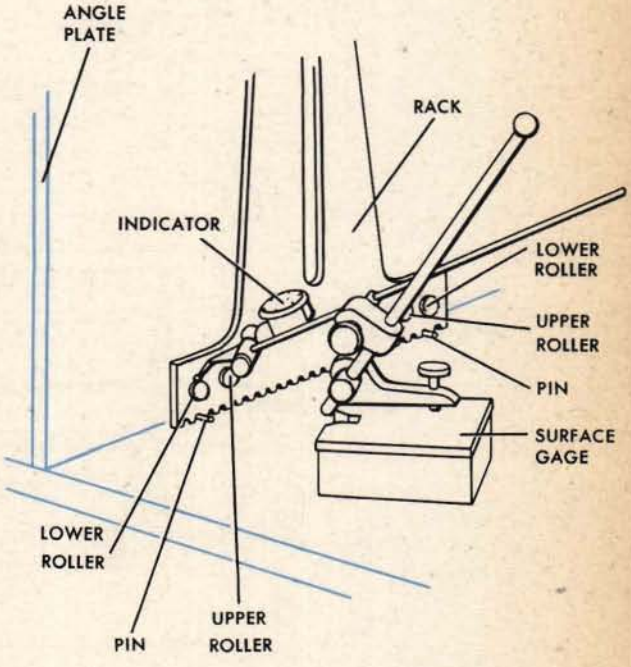
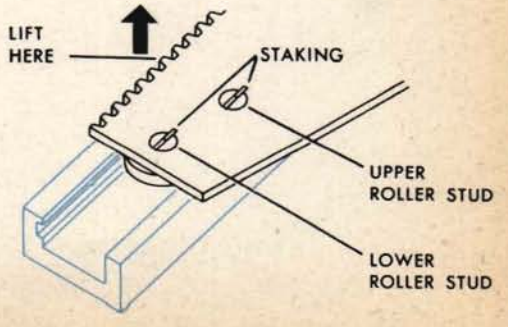
For an explanation of removing and replacing a riveted stud, see pages 76-79.





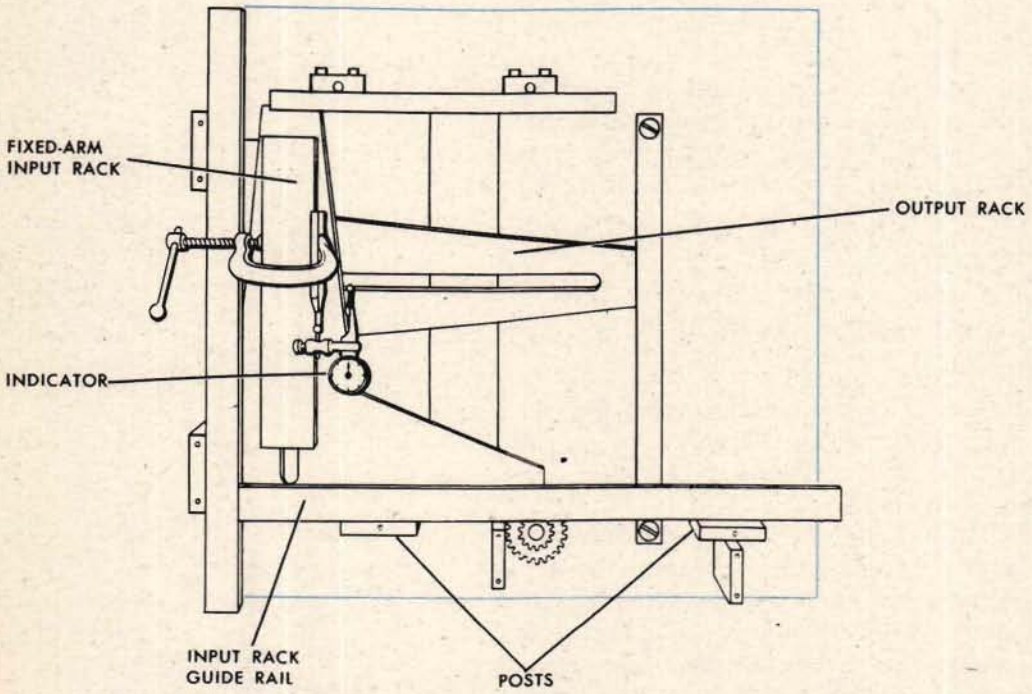
Squaring the racks

The slots in the fixed-arm input and the output racks must be at right angles to each other.

First reassemble on the plate the fixed-arm input and the output racks, their rails, and guides. Do not install the slide blocks and the pivot-arm input rack.

Wedge the output rack. Then mount a dial indicator firmly on the input rack with the point of the indicator on one face of the slot in the output rack. Move the input rack through its full travel. Observe the reading of the dial as the indicator point moves along the face of the output rack slot.

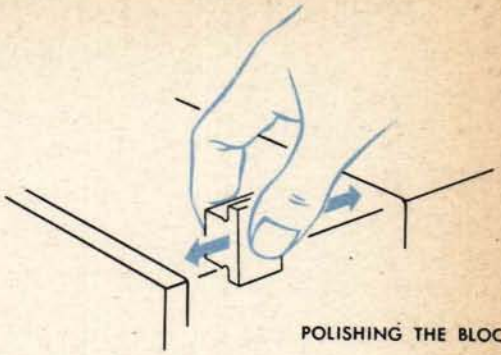
If the indicator reading exceeds 0.001 inch, check the setting of the lower rollers in the output rack as explained on page 209. It is advisable to check the lower rollers of the fixed-arm input rack at the same time. Replace the two racks and repeat the check for squareness.



If the indicator reading still exceeds 0.001 inch, reposition the fixed-arm input rack rail. To do this, first remove the dowels from the posts holding the rail. Then adjust the position of the posts until a true reading is obtained. Tighten the post screws. Use oversize dowels to redowel the posts.

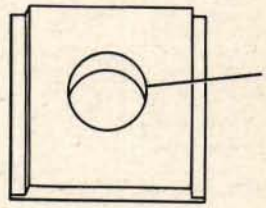
Fitting new slide blocks in the racks

Smooth any burred or rough edge of the block with a fine oilstone. Remove any extremely sharp edges, but leave them square. It is very important not to round or chamfer the edges.



POLISHING THE BLOCK

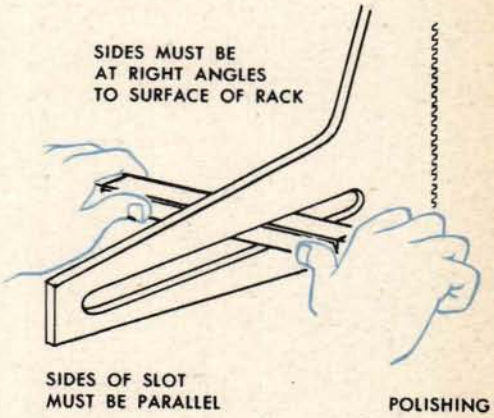
To reduce the width of the block, polish the sides on a piece of crocus cloth placed on a flat surface. Remove equal amounts from both sides so that the hole in the block remains centered. Use long, even strokes while holding the block square. Check it occasionally with a micrometer to be sure that the sides are parallel.



SIDES MUST BE PARALLEL

Polish the block to a close fit in the widest part of the slot. Then polish the rest of the slot to fit the block, using crocus cloth wrapped once around a square steel bar. Keep the sides of the slot parallel to each other and at right angles to both the flat surface of the rack and the pitch line of the rack teeth.

Before trying the block in the slot, wash with an approved solvent, dry and lubricate both parts thoroughly. The fit is right when the block can be moved the full length of the slot. Move the block back and forth by hand until it travels the full length smoothly.

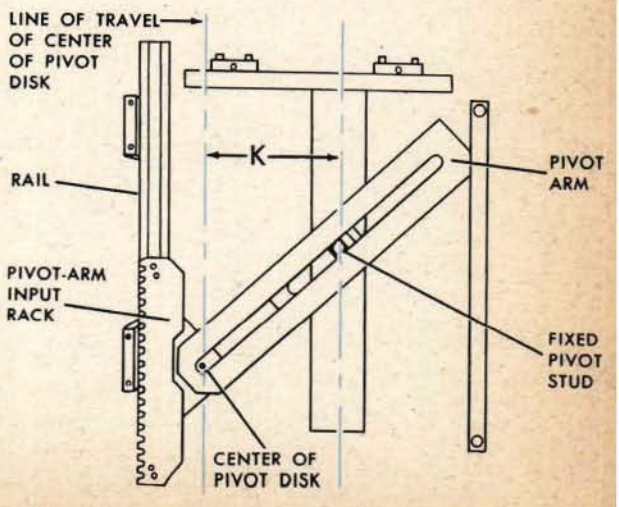


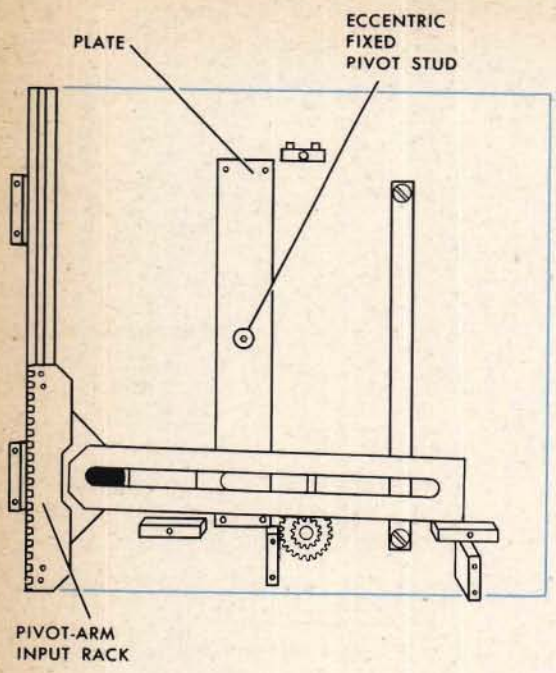
POLISHING THE SLOT

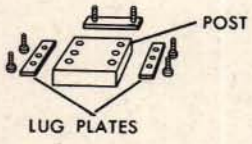
Replacing the pivot studs

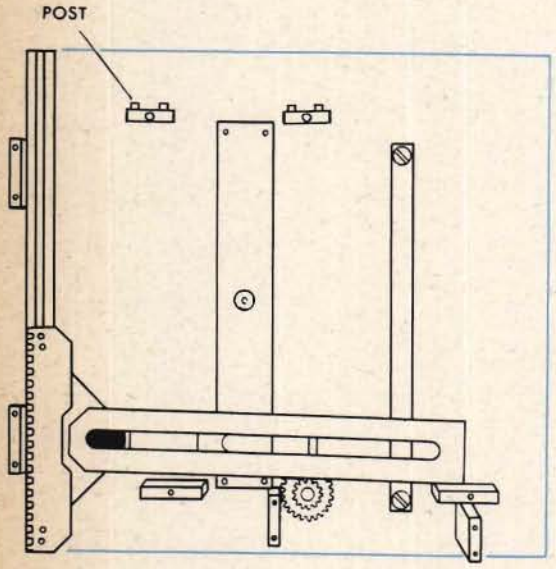
For instructions on removing and riveting the multiplier stud in the fixed-arm input rack slide block and the fixed pivot stud in the plate, refer to pages 76-79.

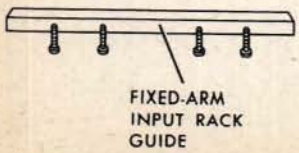
The distance between the center of the fixed pivot stud and the line of travel of the pivot disk must be correct in order to obtain the correct output from the multiplier. This distance, which represents the constant, *K*, in the mathematical explanation of the multiplier, is designated on the assembly drawing. Turn the fixed pivot stud, which is eccentric, until the exact measurement is obtained; then "stake" the plate in order to hold the stud in position.











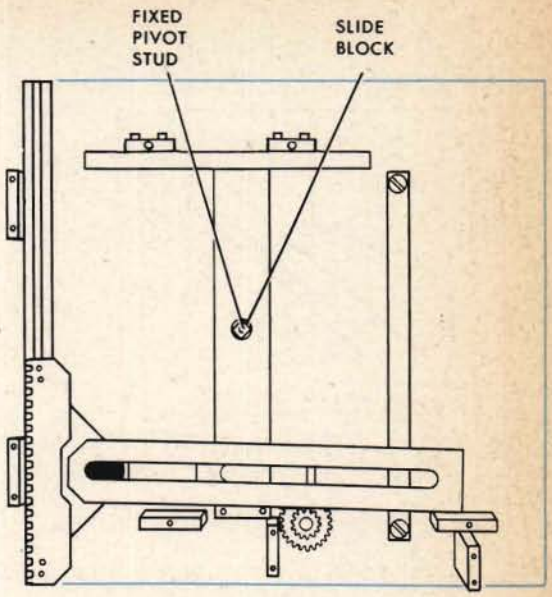
Reassembling the unit

1 Mount the plate holding the eccentric fixed pivot stud. Tighten the four screws.

2 Mount the pivot-arm input rack by sliding it down in its rail.

3 Mount the post and secure it to the base plate.

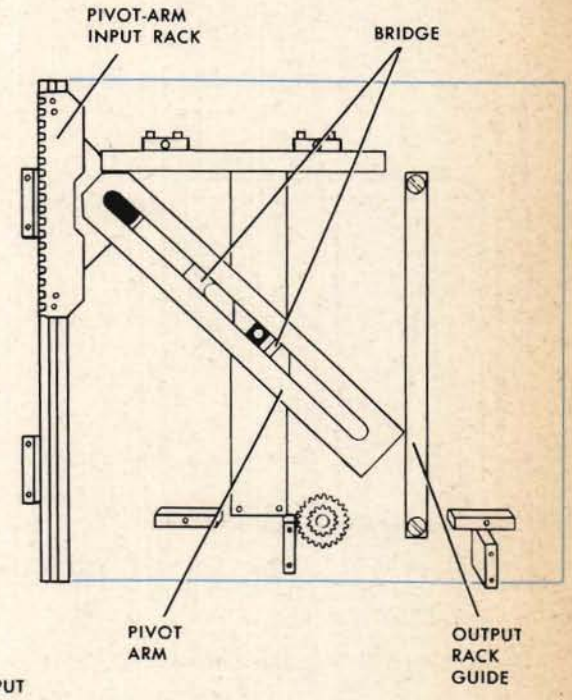
4 Mount the fixed-arm input rack guide so that the side which is nearer the slot will be toward the base plate.



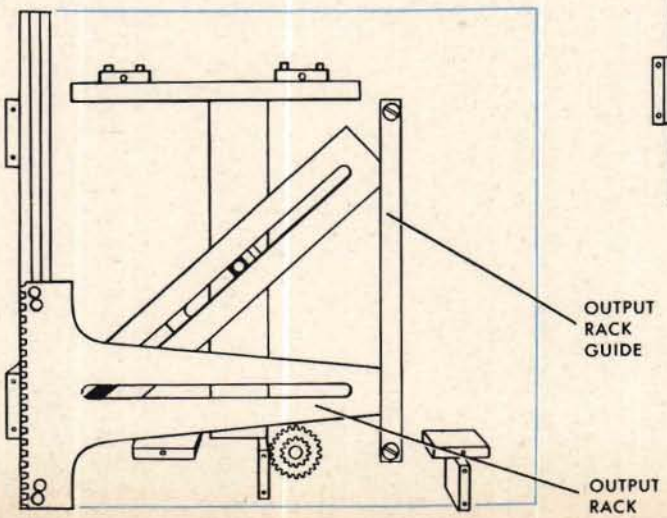
5 Place the slide block (flanges up) on the fixed pivot stud.

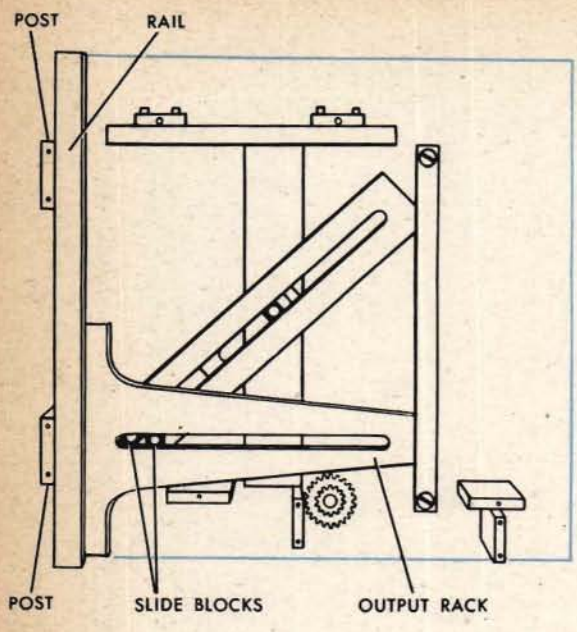
6 Put the spacer and snap ring on the fixed pivot stud.

7 Move the pivot arm to align the cutaway section of the bridge with the slide block on the fixed pivot stud. Then carefully move the pivot arm until the slide block rides into the bridge slot and the end of the pivot arm goes under the output rack guide.



8 Place the end of the output rack in its guide.

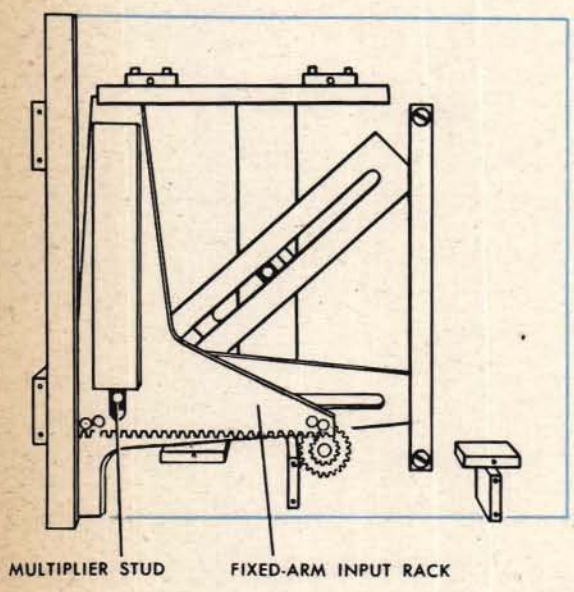




9 Slide the rail on the output rack rollers. Fasten the rail to the posts.

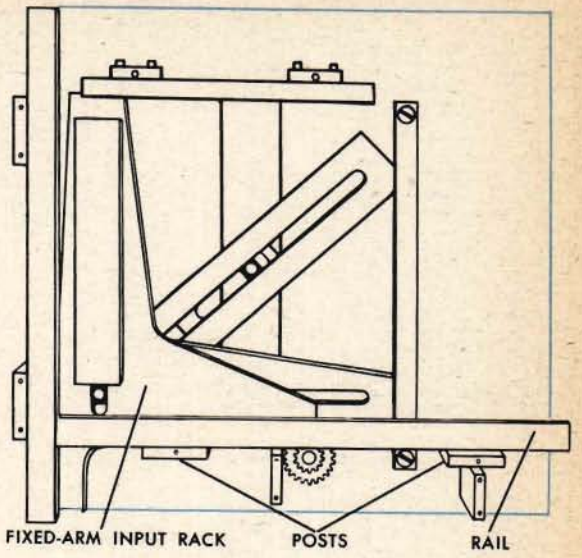
10 Place the slide blocks in the output rack slot and in the pivot arm slot.

11 Align the holes in the two slide blocks.



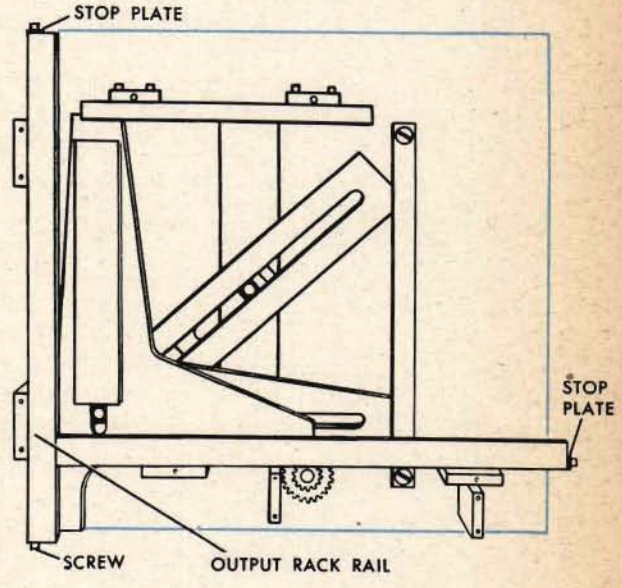
12 Set the end of the fixed-arm input rack in its guide and put the multiplier stud through the holes in the two slide blocks.

13 Slide the rail on the fixed-arm input rack rollers. Fasten the rail to the posts.



14 Fasten the rail of the output rack to the bottom stop plate.

15 Mount the two stop plates.



Bench checking the unit

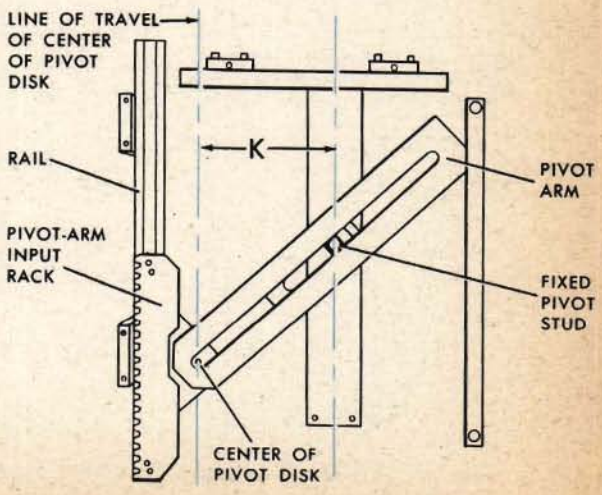
1 Check the unit against the assembly drawings.

2 All the gear meshes must be free and have a minimum of lost motion.

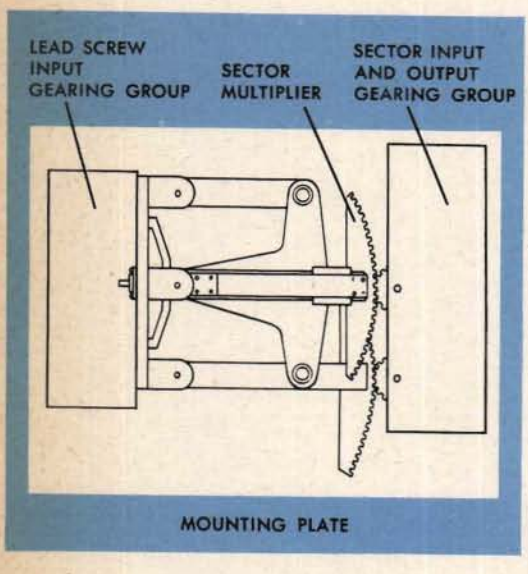
3 The racks must move freely through their full travel.

4 The eccentric roller studs in the racks and the eccentric fixed pivot stud must be tight and staked.

5 The distance, *K*, between the center of the fixed pivot stud and the line described by the center of the pivot disk as the pivot-arm input rack is moved through its travel must agree with the distance indicated on the assembly drawing.



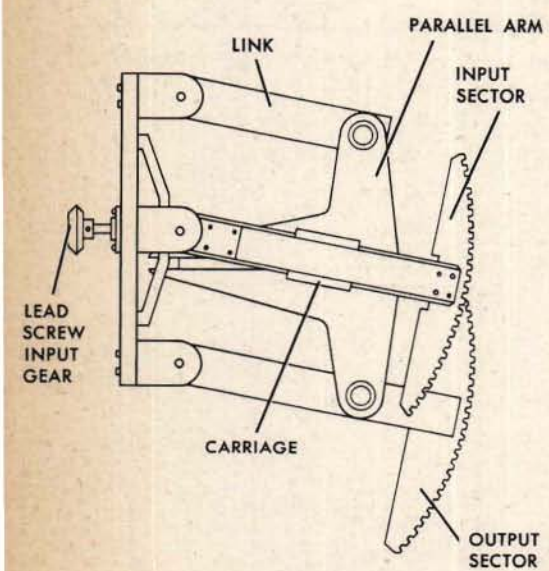
THE SECTOR TYPE MULTIPLIER



Sector multipliers are usually mounted in groups. They are mounted side by side, and the whole group forms one assembly. In a multiplier group, all the lead-screw input gearing makes up one gearing group at one end of the assembly. At the opposite end, all the sector input and output gearing makes up another gearing group.

In order to remove one multiplier, it is usually necessary to remove the entire sector gearing group connecting with all the multipliers. Before this gearing group is removed, however, the trouble must be exactly located in one multiplier. If the unit must be removed for repair, consult the instrument OP for instructions.

Typical symptoms



If a test analysis and unit check tests have indicated that a sector multiplier is not operating normally, look for the following typical symptoms:

LEAD SCREW INPUT—JAMMING: The lead-screw input gear cannot be turned by hand.

LEAD SCREW INPUT—STICKING: The lead-screw input gear resists turning past a certain point or points, or turns sluggishly.

LEAD SCREW INPUT—EXCESSIVE LOST MOTION: There is too great a lag between the turning of the gear and the movement of the traveling nut and carriage.

LEAD SCREW INPUT—SLIPPING: Turning the lead-screw input gear moves the traveling nut and carriage only intermittently.

SECTORS—JAMMING: One or both sectors cannot be moved by hand.

SECTORS—STICKING: One or both sectors resist moving past a certain point or points, or move sluggishly.

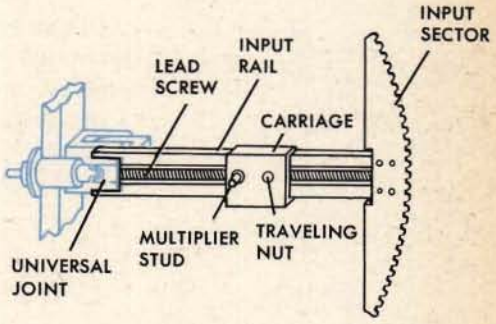
SECTORS—EXCESSIVE LOST MOTION: When one sector is held stationary and the other is shaken, there is too much play between them.

SECTORS—SLIPPING: Moving either input does not move the output.

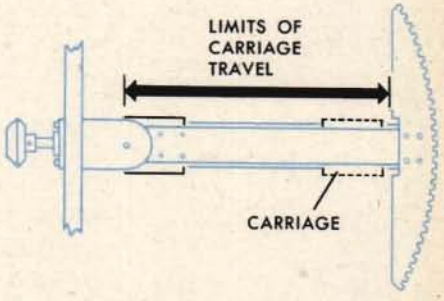
Locating the cause

Lead screw input: jamming or sticking

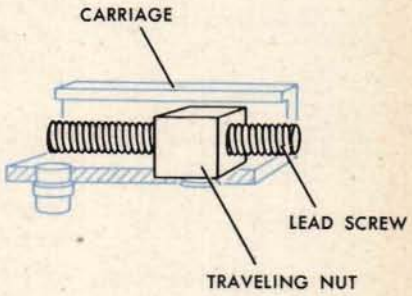
A lead screw may jam or stick because the traveling nut has run too far in or out; or because of dirty or defective threads in the nut or on the screw; or because of a bent screw. If any of these parts needs to be replaced, the unit should be removed from the instrument for disassembly.



If the traveling nut has run beyond its normal travel and jammed against adjoining parts, it can usually be backed out of its position by hand. Try to move it by turning the lead-screw input gear. After it comes free, run the traveling nut through its full travel to be sure that the nut and screw threads are undamaged. This type of jamming is caused by an incorrect limit-stop setting. Directions for re-setting the limit stop are given in the instrument manual.



If the traveling nut sticks or binds at only one point, the lead-screw threads are probably the cause. Examine them closely at this point. Remove any dirt or embedded particles. Then lubricate the lead screw and run the carriage back and forth by turning the input gear until the nut travels smoothly. A badly damaged or bent lead screw should be replaced.



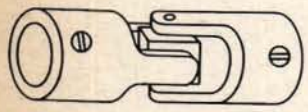
If the traveling nut sticks or binds along its entire travel, the cause of the trouble may be dirty or damaged threads in the nut. The nut should be removed for repair.

NOTE: Check lead screw and traveling nut for lost motion after correcting any jamming or sticking.

Lead screw input: excessive lost motion

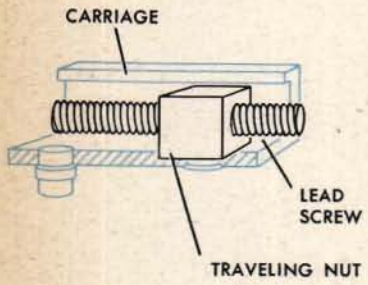
The assembly drawing specifies the allowable maximum of lost motion between the lead-screw input gear and the parallel arm. Excessive lost motion may be caused by worn threads on the lead screw or in the traveling nut, or by worn parts in the universal joint.

THE UNIVERSAL JOINT



Inspect these parts for wear, and replace any that are worn enough to cause excessive lost motion. To remove the lead screw or universal joint, or to tighten or replace a nut, the multiplier should be removed from the instrument.

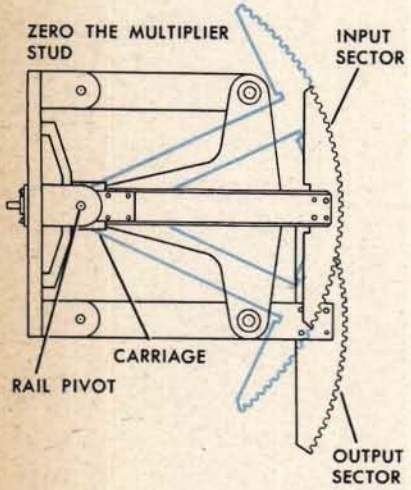
Lead screw input: slipping



Slipping may be caused by sheared pins in the lead screw, the input shaft, or the universal joint, or by stripped threads on the lead screw or nut. Repairing any of these parts requires removal and disassembly of the unit.

Sectors: jamming or sticking

Move the input sector through its full travel to check the smoothness of operation. If it jams or sticks, the cause of the trouble is in either the input or the output sector.



Turn the lead screw until the multiplier stud is over the rail pivot to obtain zero movement of the output sector. Then move the input sector through its full travel. If the input sector binds or jams while the stud is in this position, the trouble may be caused by a damaged rail pivot, damaged gear teeth on the input sector, or the slide block frozen on the stud.

If the input sector travels smoothly when the output sector is centered, and jerkily when the output sector is moved, the cause of the trouble may be the gear teeth on the output sector, the pivot studs, or the slide block or slot in the parallel arm.

Repairing any of the parts requires removal and disassembly of the unit.

Sectors: slipping

If moving either input does not move the output sector, the trouble is probably caused by a missing or sheared stud. If turning the lead-screw input gear does not turn the output sector, the trouble is probably caused by sheared or missing pins in the universal joint. Replacing any of these parts requires removal and disassembly of the unit.

Sectors: excessive lost motion between them

Excessive lost motion between the sectors may be caused by a loose, worn, or bent multiplier stud, a worn slide block or slot in the parallel arm, or a worn pivot stud.

A worn stud, slide block, parallel arm slot, or pivot stud cannot be repaired. The worn parts should be replaced.

Sectors: excessive lost motion at the gear teeth

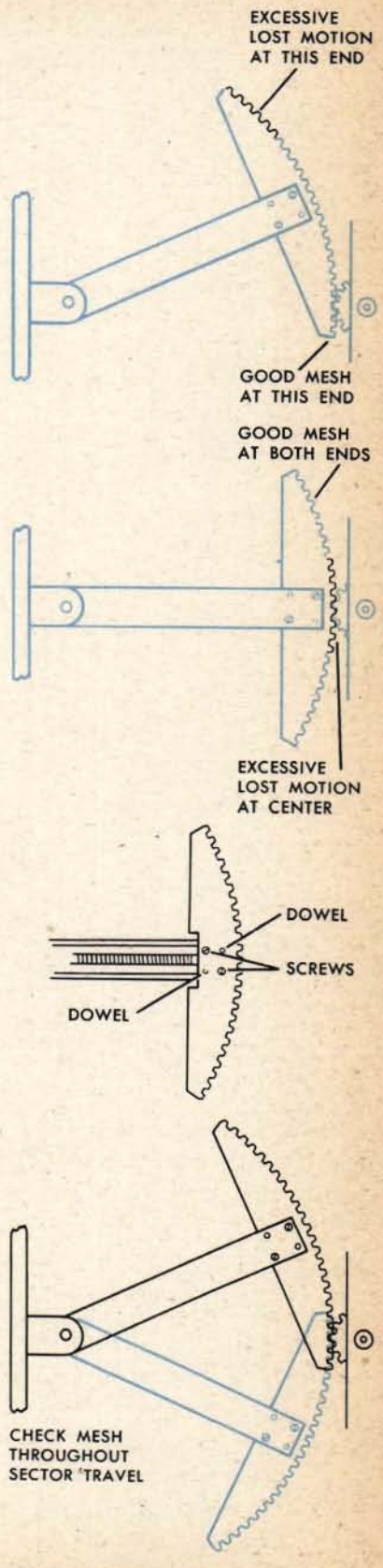
A sector which has excessive lost motion at the gear teeth, either at one end or along its entire travel, can often be repositioned on its arm. A sector which has excessive lost motion only at the center gear teeth and correct lost motion at both ends should be replaced. Repositioning or replacing a sector does not necessarily require removal and disassembly of the unit.

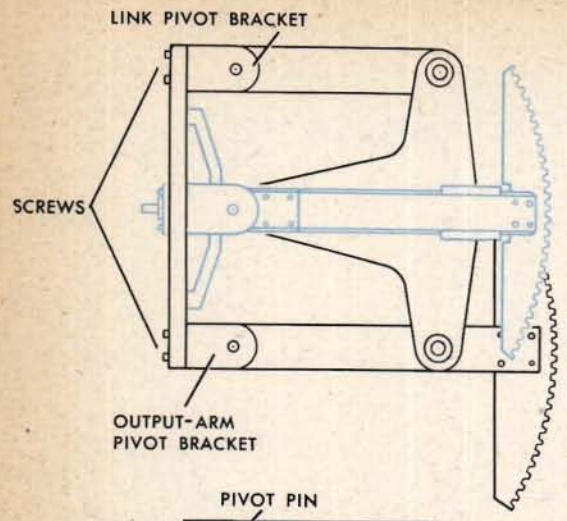
Adjusting or replacing a sector

Move the sector back and forth to see whether it can be removed without disturbing the connected gearing group. If necessary, remove the gearing group. To remove the sector from the arm, take out the two screws and tap the sector until it comes free from the dowels, which should remain on the arm.

To reposition a sector, tap out the dowels and replace it on the arm, tightening the screws only enough to hold the sector while it is repositioned. Replace the gearing group and move the sector against the screws until the gear teeth mesh correctly along its entire travel. Then tighten the screws. Protect nearby mechanisms with tissue and redowel with oversize dowels. For a detailed explanation of doweling see pages 74-75.

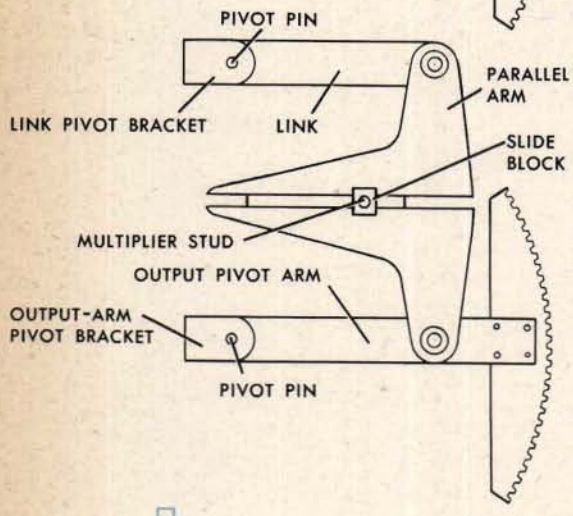
CAUTION: This procedure should be followed only in an emergency. Preferably, the sector and arm should be removed for redoweling after the gear mesh has been adjusted.





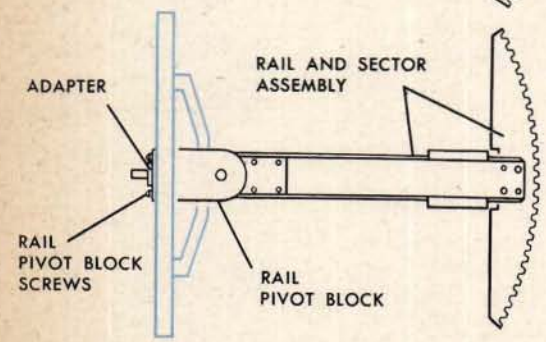
Disassembling the unit

1 Remove the screws holding the link pivot bracket and the output-arm pivot bracket to the base plate.



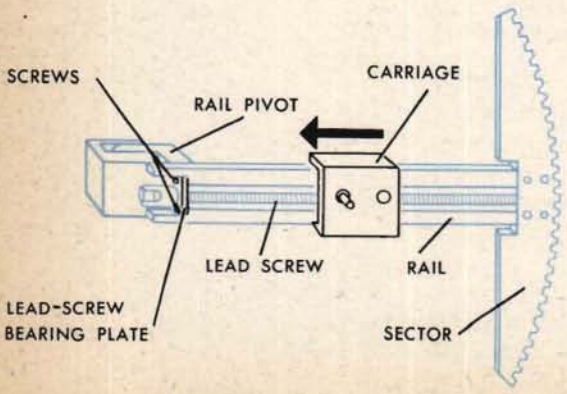
2 Slide out the assembly consisting of the two pivot brackets, the output arm, the parallel arm, and the link. Remove the slide block from the multiplier stud.

Do not disassemble this group unless the pivot pins or the parallel arm require replacement.



3 Remove the lead-screw input adapter from the base plate.

4 Remove the screws that hold the rail pivot block to the base plate and lift off the rail and sector assembly.



5 Remove the two screws holding the lead-screw bearing plate and turn the lead screw out of the traveling nut.

6 Slide the carriage off the rail.

7 Do not remove the sector from the rail unless the sector must be repositioned or replaced.

8 Do not remove the rail pivot unless it must be replaced.

Repairing the parts

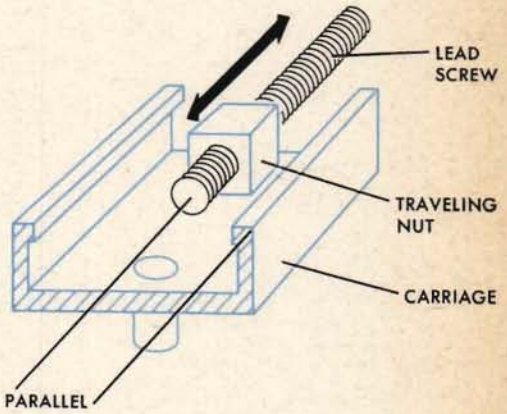
Fitting a new lead screw

Inspect the new lead screw for nicks or dirt in the threads. Make sure that the threads are not bent or turned at the ends of the screw. Remove dirt or foreign matter, and smooth out small nicks. Make sure that the traveling nut threads are clean and undamaged.

Apply lubricant to both parts and start the screw into the nut slowly and carefully. Run it back and forth in the nut until it moves smoothly throughout its travel.

Remove the lead screw from the nut and fit it to the bearing plate and the universal coupling end. Pin the coupling end to the lead screw.

Finally, wash all the parts thoroughly in a suitable solvent and relubricate them.

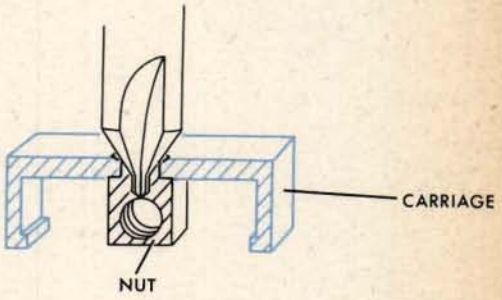


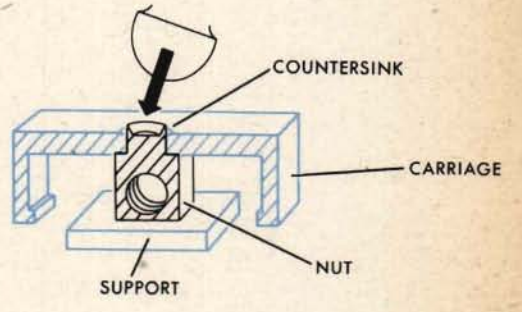
Replacing a traveling nut or multiplier stud

Remove the riveted portion with a center drill, and support the carriage to prevent distortion while driving out the old part with a punch and a light hammer.

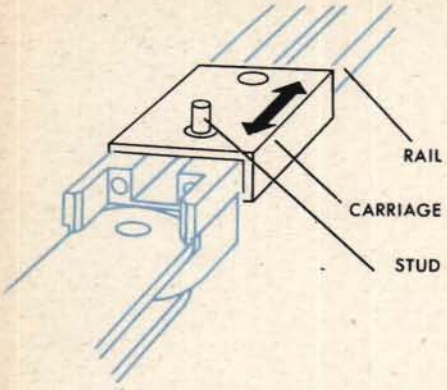
TO REPLACE A NUT, first fit the new nut to the screw. Then remove the nut and fit it in the carriage hole. Finally, support the head of the nut and tap with a ball peen hammer until the lip is brought down evenly into the countersink in the carriage. Be very careful not to distort the threaded hole by hammering too hard. Position the nut so that the lead screw will be parallel to the side of the carriage.

TO REPLACE A STUD, first fit the stud to the slide block. Then insert it in the hole in the carriage. Support the carriage and peen over the end of the stud.





For a detailed explanation of removing and replacing parts which are riveted in this way, see pages 77-79.

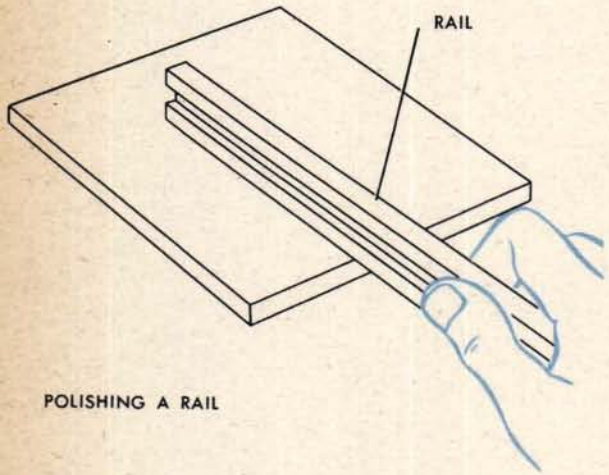


Fitting a new carriage to a rail

First fit and rivet a new stud and a new nut to the carriage. Then lubricate both the carriage and the rail.

With the lead screw removed, carefully start the carriage on the rail. If it does not start easily, do not force it, because forcing it will raise a burr.

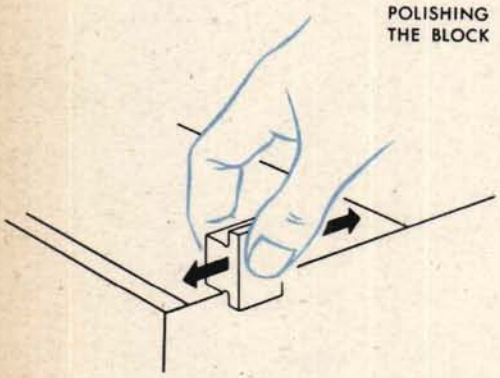
In fitting a new carriage, polish only the sliding surfaces of the rail—never of the carriage. Polish the rail by rubbing it lightly and evenly against a very fine abrasive cloth or paper placed on a smooth, flat surface. Try the carriage on the rail frequently in order to avoid polishing the sliding surfaces down too much. The operation is complete when the carriage moves freely over the full length of the rail.



POLISHING A RAIL

Lubricate the rail and run the carriage back and forth by hand until it moves smoothly from one end to the other with a minimum of play.

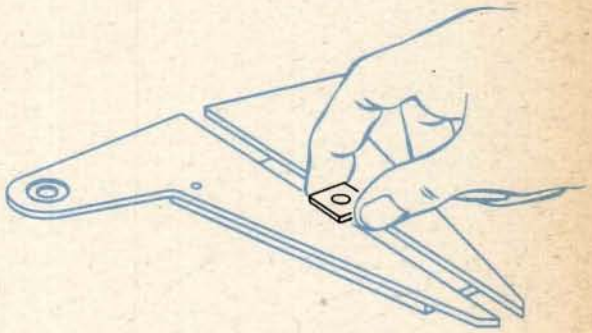
Fitting a new slide block



Use a fine oilstone to smooth burred or rough edges of the block. Remove any extremely sharp edges, but leave them square. It is very important not to round or chamfer the edges.

To reduce the width of the block, polish the sides on a piece of crocus cloth placed on a flat surface. Be sure to remove equal amounts from both sides so that the hole remains perfectly centered. Use long, even strokes while holding the block square. Measure it occasionally with a micrometer to be certain that the sides are parallel.

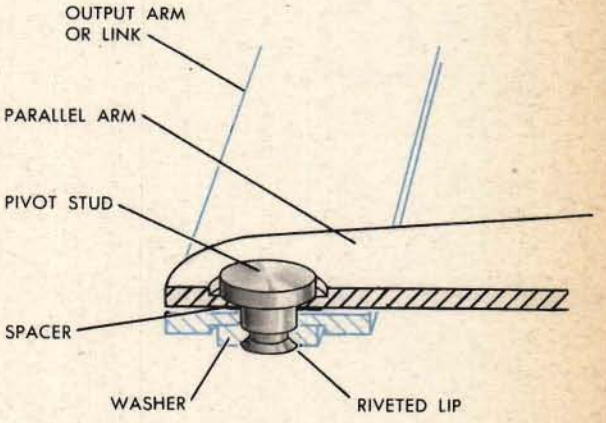
Polish the block until it is a close fit in the widest part of the slot in the parallel arm. Polish the rest of the slot to fit the block, using crocus cloth wrapped once around a steel bar. Be sure to keep the sides of the slot parallel and flat.



Before trying the block in the slot, thoroughly wash, dry, and lubricate them both. The fit is correct when the block can be moved the full length of the slot. Move the block back and forth by hand until it travels smoothly from one end to the other. Finally, wash the block and the slot again, and lubricate the slot.

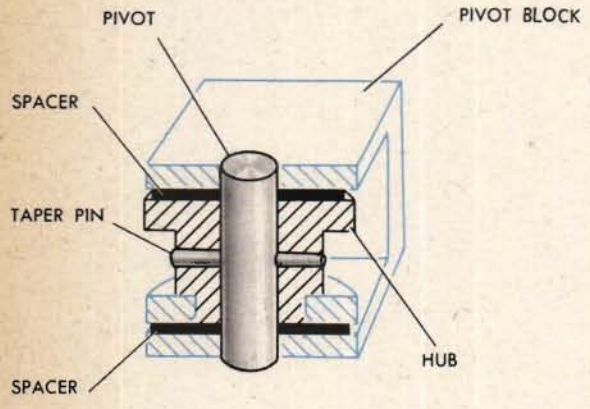
Replacing a parallel arm pivot stud

First remove the riveted portion with a center drill. Then support the arm to prevent distortion while driving out the old stud with a punch and a light hammer. Fit the new stud in the hole in the parallel arm and in the link or output arm. If necessary, ream one or both holes for a snug fit. Place the spacer between the two parts, insert the stud, and put the washer over the end of the stud. Press the washer firmly against the stud shoulder and swing the parts or rotate the stud to see whether the parts are free to turn. If the parts bind, file the spacer until they move freely. Finally, support the head of the stud and tap with a ball peen hammer to bring the lip down evenly into the countersink in the washer.



For a detailed explanation of removing and replacing parts which are riveted in this way, see pages 77-79.

Replacing an arm or link pivot

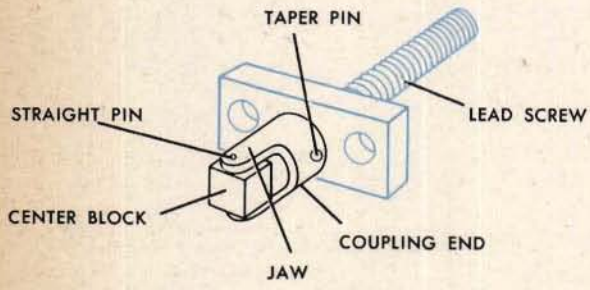


First tap out the taper pin from the small end and then drive out the pivot. Inspect the holes for wear, and if they are worn, replace the pivot block.

The new pivot must be fitted to the hole before the parts are assembled. A hard push-fit is required in a hub or rail support, and a light push-fit with no lost motion in a pivot block. If necessary, ream the holes to fit the pivot, or use a slightly oversize pivot if the standard size is too loose.

Assemble the parts with the two original spacers in place and insert the pivot. Drill a taper pin hole and seat the pin. Finally, remember to stake the large end of the pin.

Replacing a block in a universal joint



First remove the lead screw from the rail. To release the block, tap out the straight pin that fastens it to the coupling end. The new block should fit freely between the jaws without play or lost motion.

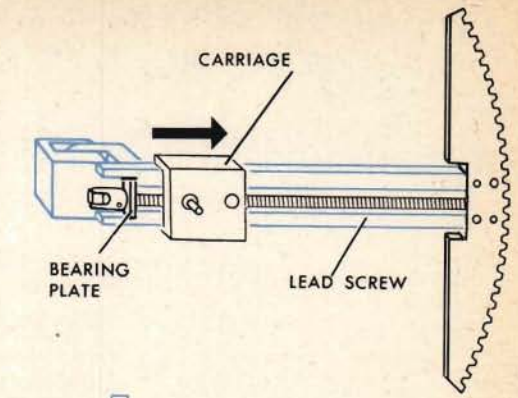
If the jaws are worn, replace the coupling end. Polish the inner surfaces of the jaws to assure smooth operation. If the block is slightly large, polish the faces until it fits between the jaws.

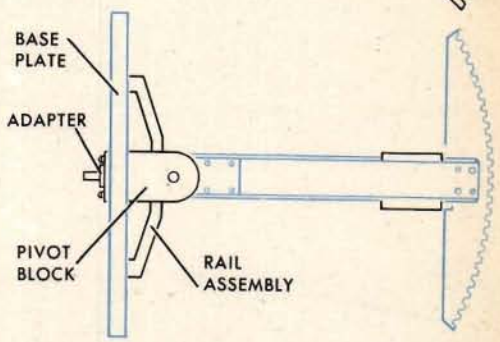
Polish the opposite faces equally on a piece of crocus cloth placed on a smooth, flat surface. When the block fits correctly, position it between the jaws and tap in the straight pin. To make sure that the pin is retained in place, stake some metal over the ends from both jaws of the coupling end. After staking, make sure that the block is still free to turn.

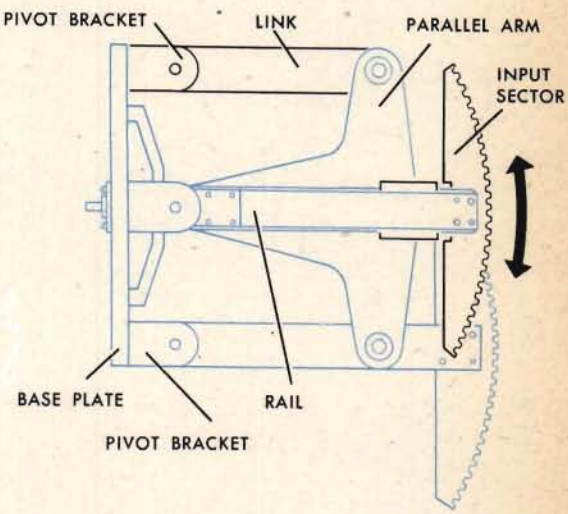
Reassembling the unit

Wash and dry all the parts before starting to reassemble the unit, and lubricate each part before replacing it.

1. Slide the carriage onto the rail.
2. Hold the carriage near the rail support and turn the lead screw through the traveling nut.
3. Fasten the bearing plate to the rail.
4. Turn the lead screw to move the carriage through its travel to check for freedom of movement.
5. Mount the rail assembly on the base plate and fasten the pivot block.
6. Replace the adapter shaft assembly. Check the alignment of the coupling and the screw.
7. Replace the slide block on the multiplier stud.
8. On the base plate, position the large assembly composed of the parallel arm, the rail, the input sector, and the link assemblies.
9. Position the slide block in the parallel arm slot.
10. Fasten the two pivot brackets to the base plate.
11. Turn the lead screw to move the carriage through its full travel to check for smoothness.
12. Move the input sector through its full travel to check for smoothness.





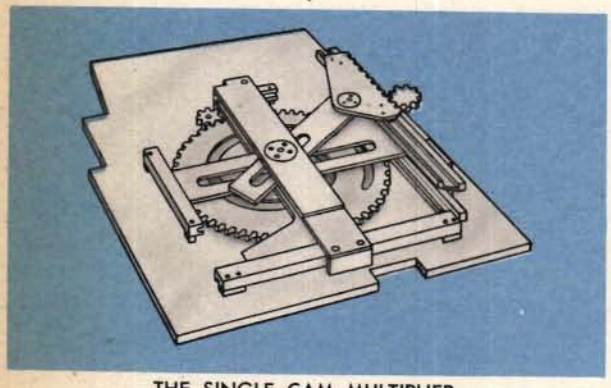


Bench checking the unit

1. Check the assembly of the unit against the assembly drawing.
2. The lead-screw input should be free when the input sector is at either end of its travel.
3. Lost motion at the universal joint should not exceed the allowable maximum specified on the assembly drawing.
4. Move the carriage until the multiplier stud is directly over the rail pivot. At this zero position, moving the input sector should not move the output sector. Mark this carriage position on the input arm with a scriber.
5. Move the carriage one inch from the marked zero position. When the input sector is held stationary, lost motion measured at the output sector teeth should not exceed the amount shown on the assembly drawings.

CAM TYPE MULTIPLIERS

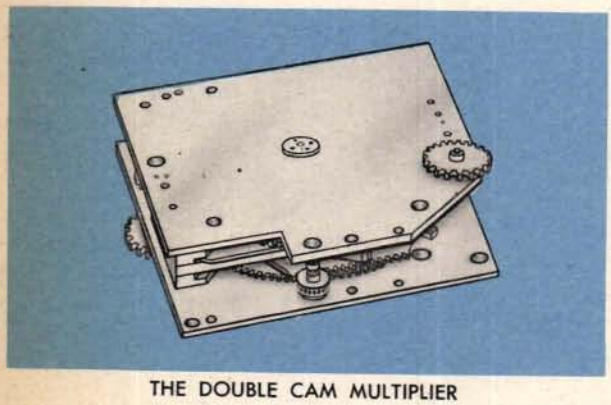
Single and double cam multipliers are similar in both construction and operation. The main mechanical difference between them is that in the single cam multiplier the pivot arm is positioned by a rack, but in the double cam multiplier it is positioned by a cam. Except for this difference, checking for symptoms of mechanical trouble is the same for both units, and the repair procedures are nearly identical. If a cam multiplier must be removed for repair, consult the instrument OP for instructions.



THE SINGLE CAM MULTIPLIER

A single cam multiplier may be mounted either on a separate base plate or on a plate with gearing groups or other units. The inputs position the cam and the pivot-arm rack. The output is taken from the fixed-arm rack.

A double cam multiplier is usually mounted on a separate base plate. All the working parts are mounted between two plates and, consequently, can be seen only from the sides. The inputs position the cams while the output is taken from the output rack. In certain applications of this unit, an intermediate output is taken from the cam follower slide.



THE DOUBLE CAM MULTIPLIER

Usually one spiral cam and one square cam are used in the double cam multiplier, but in some cases both cams are of the spiral type. A square cam has a continuous groove which allows it to make any number of turns in either direction. A spiral cam turns only until the follower reaches either end of the groove.

A SPIRAL CAM

A SQUARE CAM

Typical symptoms

If a test analysis and a unit check test indicate that a cam type multiplier is not operating normally, look for one or more of the following typical symptoms:

JAMMING: One or both inputs cannot be moved by hand.

STICKING: One or both inputs resist moving past a certain point or points, or move sluggishly.

EXCESSIVE LOST MOTION: There is too great a lag between the movement of an input and an output; or when the inputs are held and the output shaken, there is too much play between them.

SLIPPING: Moving the inputs does not move the output, or moves it only intermittently.

Locating the cause

Jamming: single cam unit

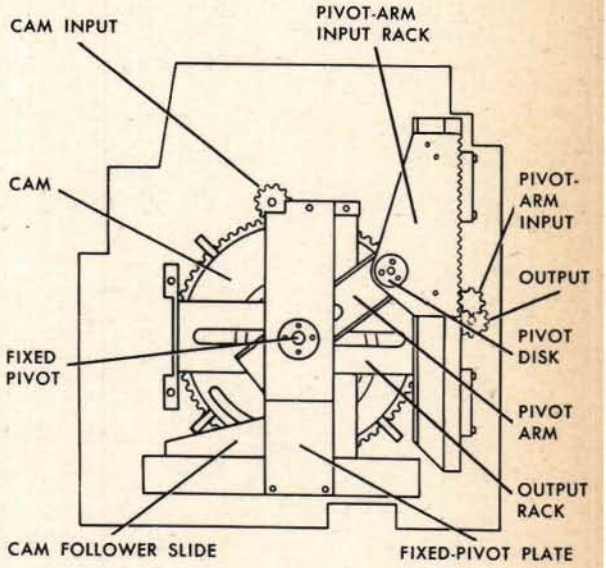
Try both inputs to determine whether one or both are jammed.

If neither input can be moved, the channel may be binding on the pivot arm or the slide block may be jammed in the cam follower slide.

If only the pivot-arm input is jammed, look for one of the following casualties: a slide block frozen on the multiplier stud, the carriage block binding in its slot or on the fixed pivot, a frozen pivot disk on the pivot-arm rack, the rollers of the pivot-arm rack jammed in the rail, or a damaged gear or rack tooth.

If only the cam input is jammed, the trouble may be due to dirt or chips in the cam groove, the slide block frozen in the output-rack slot, jamming of the cam follower slide rollers in the rail, or a damaged cam or input-gear tooth.

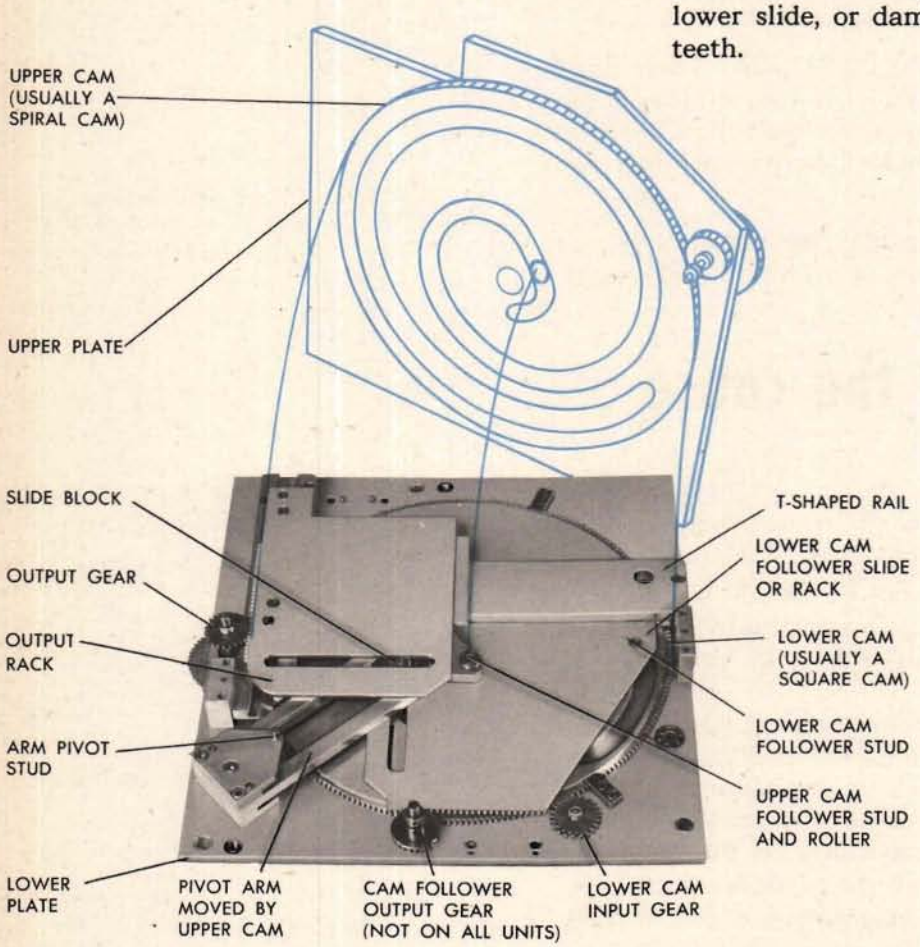
When the cam will turn only if the input rack is free to move, a jammed output rack is indicated. This may be caused by the rack rollers jamming in the rail, the slide block freezing in the cam follower slide, or damaged output rack teeth.



THE SINGLE CAM MULTIPLIER

Jamming: double cam unit

If neither of the cams will turn when both are in an active position (off zero), the slide block may be frozen in the pivot-arm slot or the output rack may be jammed. Jamming of the output rack may be caused by the rack rollers jamming in the rail, the slide block freezing in the cam follower slide, or damaged output-rack teeth.

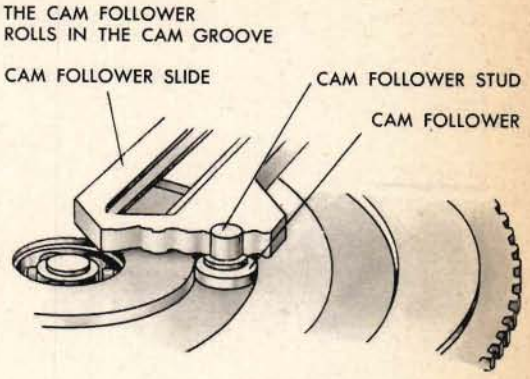


If only the lower cam is jammed, look for one of the following troubles: dirt or chips in the cam groove, the rollers of the cam follower slide jammed in the rail, the output-rack slide block frozen in its slot, or a damaged tooth on the cam or cam follower slide.

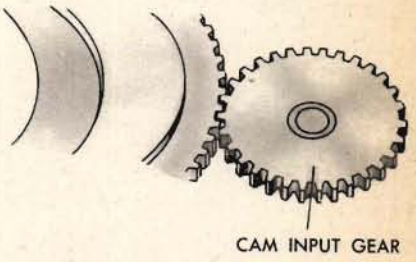
If the upper cam alone is jammed, the trouble may be caused by dirt or chips in the cam groove, or damaged cam teeth.

Cam: jamming

If a spiral cam is jammed at either end of its travel, try to move it out of the jammed position by hand. If the cam cannot be freed in this way, the cam-follower stud is probably bent, and the unit should be disassembled to repair it. This type of jamming is caused by an incorrect limit-stop adjustment. Instructions for readjustment are given in the instrument OP.

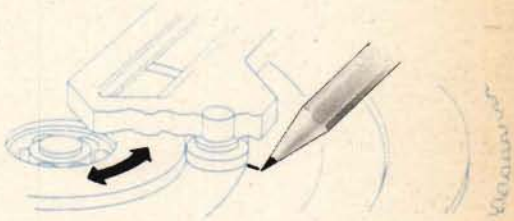


If either a square or spiral cam is jammed within its normal travel, the cause may be damaged teeth, a cam follower locked in its groove because of dirt or damage, or a bent follower stud. To repair the cam groove or any parts of the follower, the unit should be disassembled.



Cam: sticking

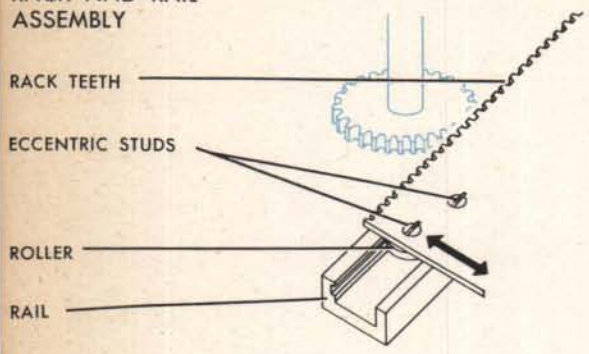
First inspect the teeth of the cam and its meshing gear at the point where these parts stick. Damaged or dirty teeth can sometimes be repaired in place.



If the gears are not causing the cam to stick, turn it through its travel several times. As the cam moves, observe the position of the follower. If the cam sticks at the same place during each travel, mark the follower position on the face of the cam. Turn the cam until this part of the groove is visible. Wipe the groove clean with tissue and inspect it carefully for damage. Remove any foreign material or embedded particles.

Polish tight or rough spots with crocus cloth wrapped around a steel bar, being very careful not to enlarge the groove. Clean the groove thoroughly and lubricate it before turning the cam again.

RACK AND RAIL ASSEMBLY

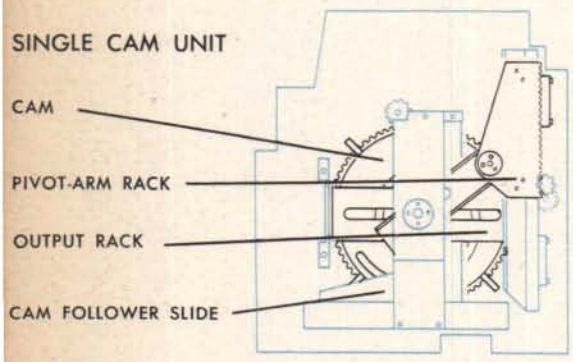


Rack: sticking

If a rack sticks, inspect the rack and gear teeth for dirt or damage. Clean or repair them if necessary. A rack or gear with badly damaged teeth should be replaced.

Slight sticking can usually be eliminated by wiping the sliding surfaces clean, lubricating them, and running the sticking parts back and forth by hand. Do not disassemble the unit to make this repair unless it sticks enough to cause serious errors in the operation of the instrument.

SINGLE CAM UNIT

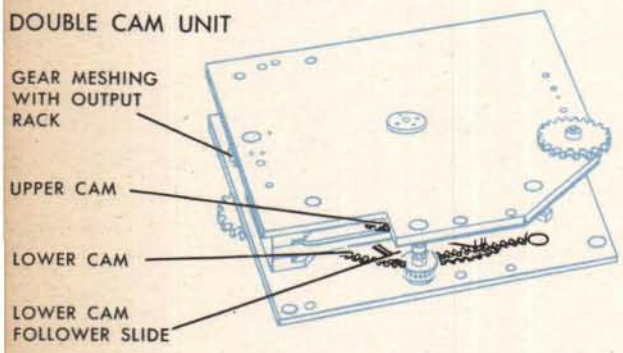


Excessive lost motion

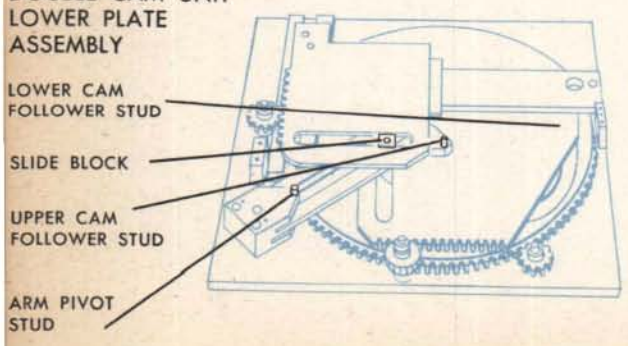
Shake each rack or slide to check for lost motion between the rollers and the rail. If the lost motion exceeds 0.001 inch, the piece should be removed in order to reposition the rollers.

To check for lost motion in the other parts, hold the output rack, position the spiral-cam follower at different points along its travel, and shake the input rack or cam. Excessive lost motion between these parts may be caused by a worn slide block or slot, or by a worn cam follower or groove. This lost motion can be reduced only by disassembling the unit and replacing the worn parts.

DOUBLE CAM UNIT



DOUBLE CAM UNIT LOWER PLATE ASSEMBLY



Slipping

Slipping may be caused by a loose rack, stripped teeth, or by a broken pivot or follower stud. Observe the movement of the output rack while both inputs are moved through their travel. The output should move smoothly and evenly while the inputs are being moved. If it does not, the fixed pivot, the slide block pivot, or a cam follower stud may be loose or sheared. To repair or replace any of these parts, the unit should be disassembled.

Disassembling the single cam unit

1 Remove the four screws that secure the fixed pivot plate and the two screws that hold the pivot-arm rack rail.

2 Tap the rail carefully to raise it off the dowels.

3 Remove the fixed pivot plate, the rack, and the rail together.

4 Remove the stop from the end of the rail and slide the rail off the rack.

5 Remove the carriage block from the fixed pivot stud. (Usually a snap ring must be removed from the stud before the carriage block will slide off.) This will separate the pivot arm from the fixed pivot plate.

6 Remove the channel from the arm.

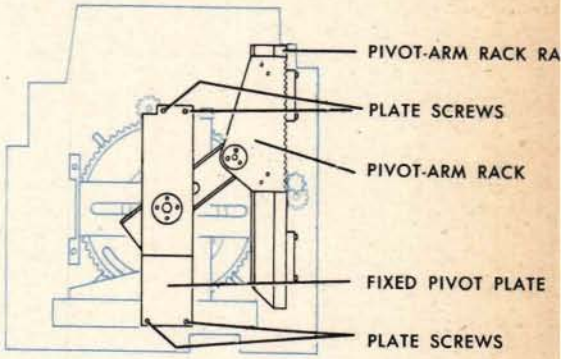
7 Remove the screws which hold the output rack rail, and lift off the rack and the rail together. Keep the slide block with the rack.

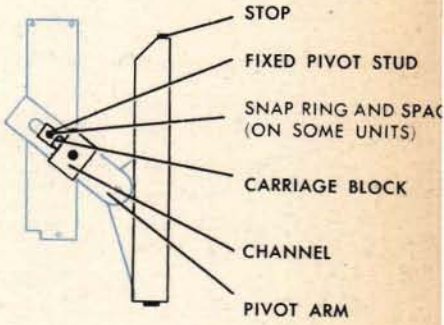
8 Remove the screws which hold the remaining slide rail and lift off the slide and the rail together.

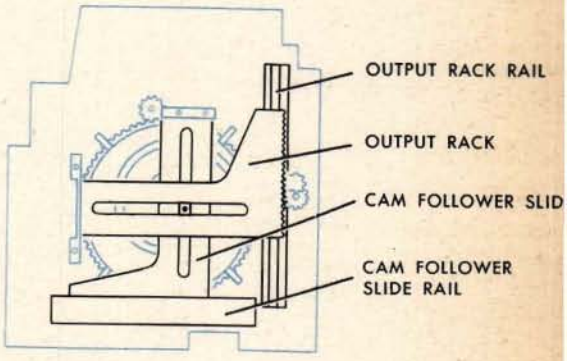
9 Remove the cam follower from the groove.

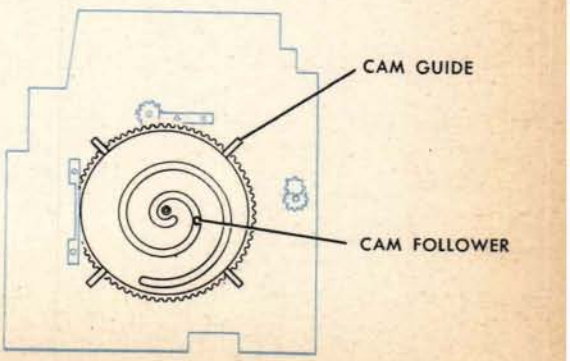
10 Remove the four cam guides.

11 Study the assembly drawing before removing the cam, because there are several methods of fastening a cam in place. Remove the cam.

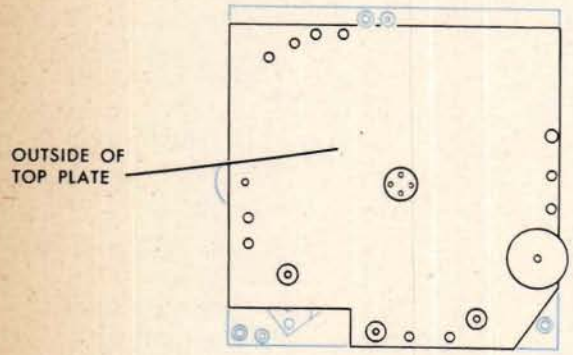




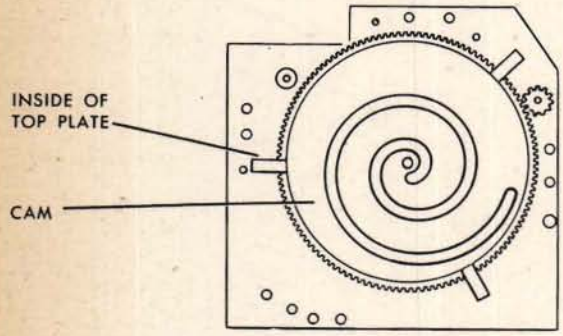




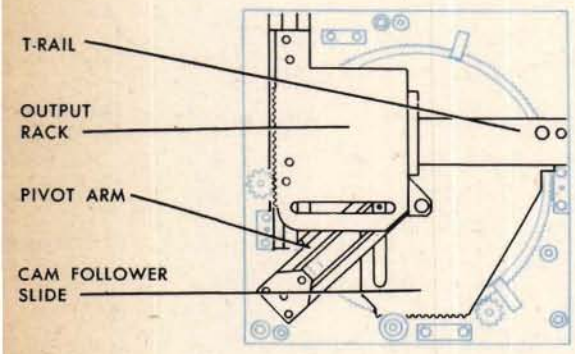
Disassembling the double cam unit



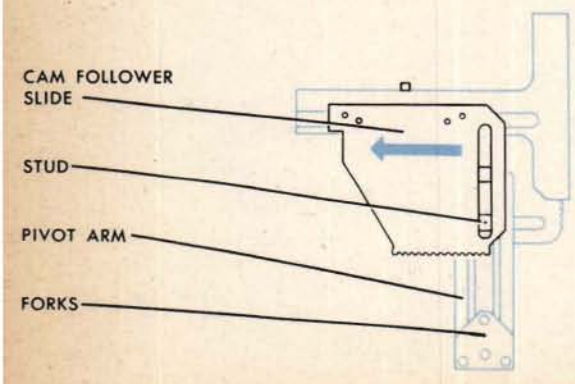
1 Remove the screws that hold the top plate to the posts.



2 Lift off the top plate and cam together. Do not remove the cam from the plate unless the cam is to be replaced.



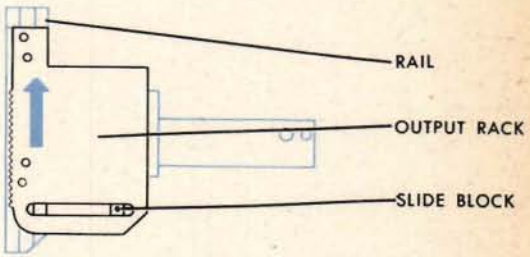
3 Remove the screws holding the T-shaped rail and carefully lift off the assembly consisting of the rail, the output rack, the pivot arm, and the cam follower slide.



4 Place this assembly on the bench with the cam follower slide on top. Raise the end of this slide high enough to clear the stud and take the slide off the rail.

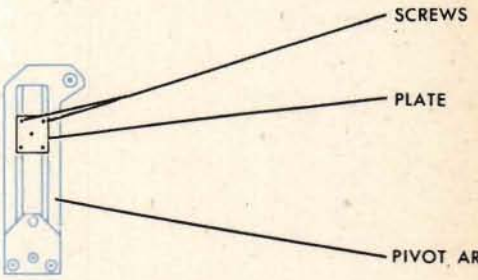
5 Lift off the pivot arm. Do not remove the two forks from the pivot arm unless they are to be replaced.

6 Slide the output rack off the rail.



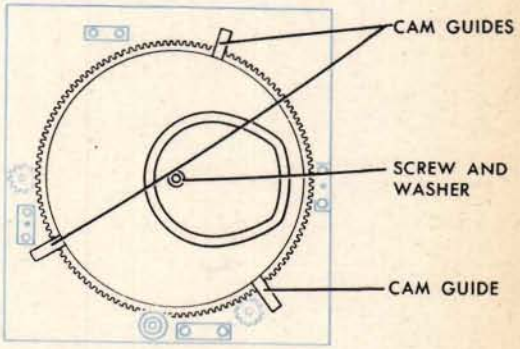
7 Note the way the slide blocks are mounted in the racks. Tie each block to the rack in which it slides.

8 Remove the four flat-head screws that hold the plate to the slide block in the pivot arm. Lift off the plate and the slide block.

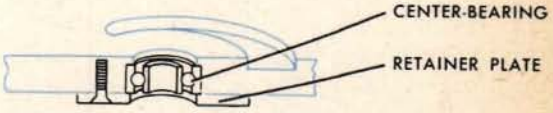


TO REMOVE EITHER CAM

9 To remove either cam from its plate, remove the center flat-head screw and washer and the guides which are on the outside edges of the cam. Lift the cam straight up.

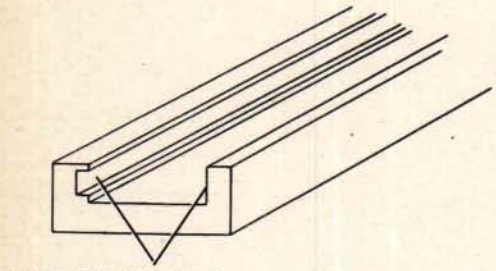


10 The cam center-bearing may be removed after the retainer plate on the back of the cam is removed.



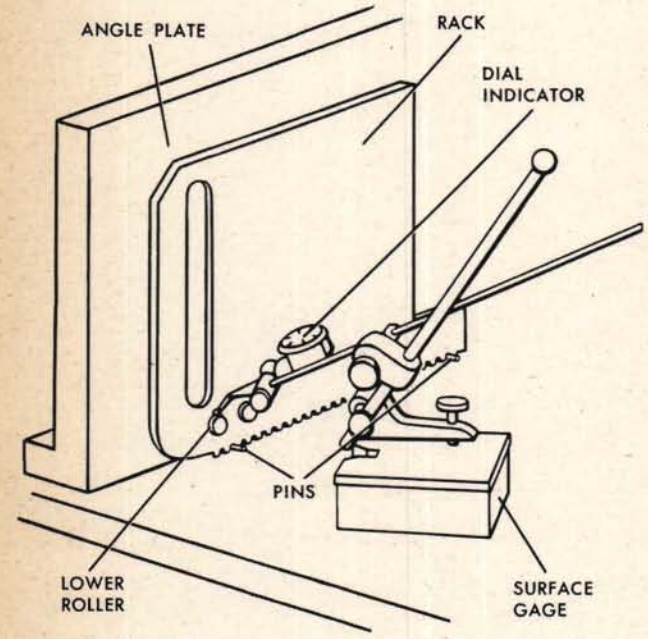
Repairing the parts

Repairing a rail



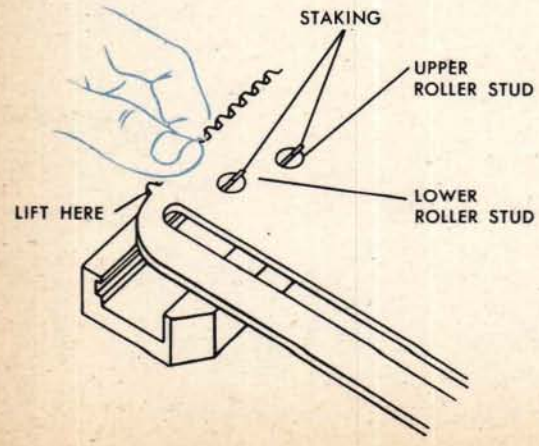
First clean the roller paths in the rail and look carefully for embedded foreign material. Then check the straightness of the roller path. Polish any rough or high spots by stroking the roller path with a square steel bar wrapped in crocus cloth, trying the rack in the rail frequently until a good fit is obtained. After completing this work, wash all the parts thoroughly with an approved solvent.

Adjusting the rollers



The lower rollers establish the pitch line of the rack in relation to its meshing gear. These rollers affect the squareness of the rack slots with respect to each other. Remove the rack and mount it against an angle plate on a surface plate. Support the rack under the teeth, using two identical pins between 0.070 and 0.075 inch in diameter. Place a pin at each end of the rack. With a surface gage and a dial indicator, measure the height of the lower rollers. The heights of these rollers must agree with the assembly drawing and be within 0.0005 inch of each other.

Double cam multiplier slide rollers are positioned a specified distance from the cam follower stud. If the slide has teeth, the lower rollers must be equal distances from the pitch line. After these rollers are repositioned, the racks and slides must be checked for squareness.



The upper rollers control the play between the rack and the rail. If the play exceeds 0.001 inch, turn the roller studs with a screw driver. A strip of feeler gage material (0.001 inch) can be used to check the clearance between the roller and the roller path. After positioning the rollers, stake a small amount of metal into the screw-driver slots of the stud heads. The rollers should be free enough in the rail for the rack to drop back of its own weight if it is raised slightly with one finger.

For an explanation of removing and replacing a riveted stud, see pages 77-79.

Squaring the rack and the slide

In both types of cam multipliers, the slots in the output rack and in the cam follower slide must be at right angles to each other.

Reassemble on the plate the output rack, the slide, the rails, and the guides. Do not reassemble the other parts of the multipliers.

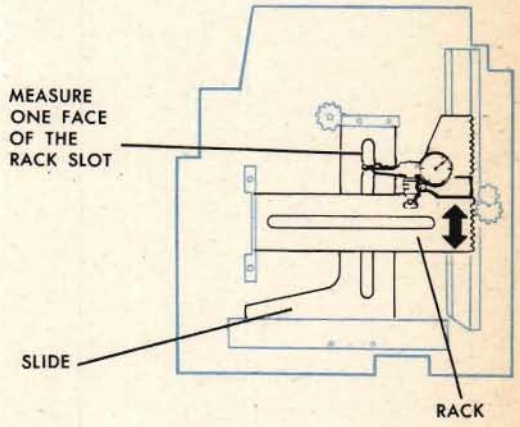
Wedge the slide. Mount a dial indicator firmly on the rack with its point on one face of the slide slot. Move the rack through its full travel and observe the reading as the point of the indicator moves along the face of the slot in the slide. Repeat this procedure with the rack wedged and the indicator mounted on the slide with its point against the face of the rack slot. If the total reading in either case exceeds 0.002 inch in 6 inches of travel, follow the instructions on the preceding page to check the setting of the lower rollers of the rack and the slide. Replace the rack and the slide and repeat the check for squareness.

In the single cam multiplier, if the reading still exceeds 0.002 inch, reposition the slide rail. First, drive the dowels out of the rail. Then replace the rail and its slide and repeat the check for squareness. If the indicator reading is still excessive, loosen the screws holding the rail, and move the rail within the clearance of its screw holes until a reading of 0.002 inch or less is obtained. Then tighten the screws and redowel the rail with oversize dowels

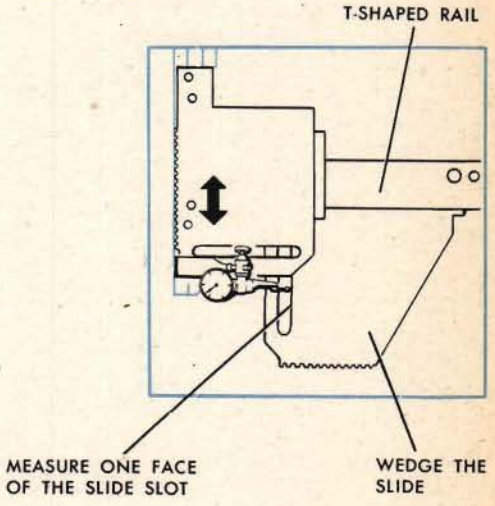
NOTE:

In a double cam unit the rack and slide roller paths cannot be repositioned with respect to each other because they are milled in one T-shaped piece of metal. Proper adjustment of the rollers assures the squareness of the slot in the rack to the slot in the slide.

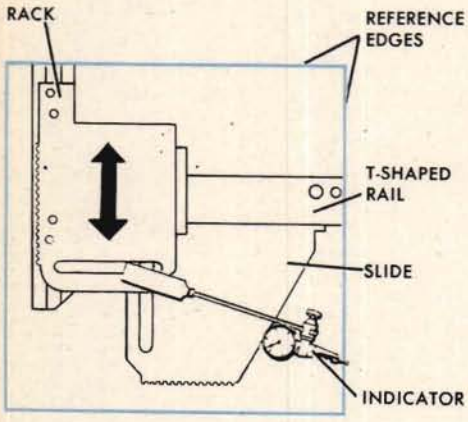
SINGLE CAM UNIT



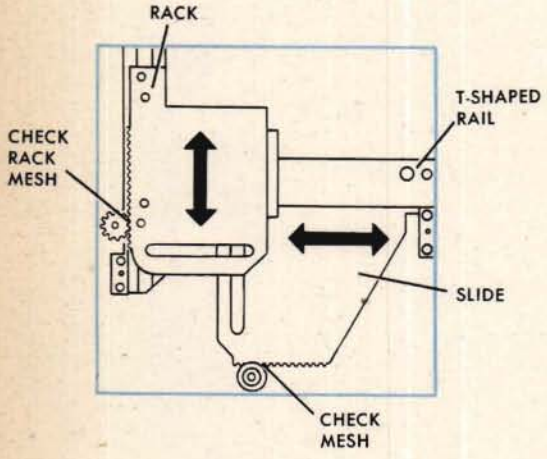
DOUBLE CAM UNIT



Positioning the T-shaped rail



In order to obtain the correct output from the double cam multiplier, the T-shaped rail must be positioned so that the rack slot will be parallel to the reference edge of the plate and so that the gear meshes at the rack and at the slide will be free, yet have a minimum amount of lost motion. Before attempting to position the rail, check that the rollers on the rack and on the slide are adjusted precisely. (Instructions for adjusting the rollers are given on page 234.)

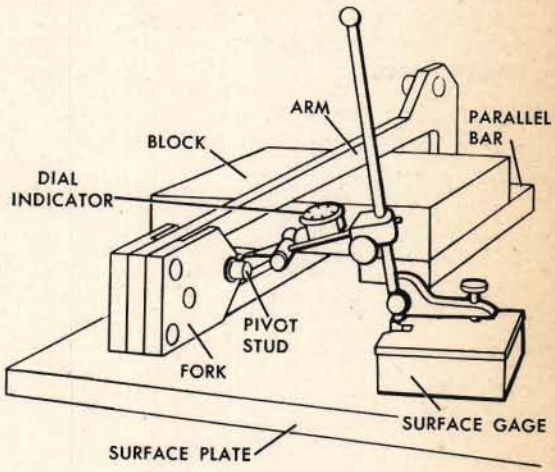


Reassemble the output rack, the slide, and the T-shaped rail on the plate. Do not mount the cams. Clamp an indicator on the output rack with its point against the reference edge of the plate. Run the rack between the limits of its travel. The plate and rail should be parallel within 0.001 inch. If the indicator reading exceeds 0.001 inch, loosen the screws and move the rail within the clearance of its screw holes until a better reading is obtained. Remove the indicator and temporarily replace the top plate. Try the rack and pinion meshes. If the meshes are free, with a minimum of lost motion, remove the plate, tighten the screws, and redowel the rail with oversize dowels.

If the meshes are not correct, shift the rail until good meshes are obtained. Remove the top plate and recheck that the rack slot is parallel to the edge of the plate. Check the meshes again. When these two requirements are met, redowel the rail with oversize dowels.

Repairing the pivot studs

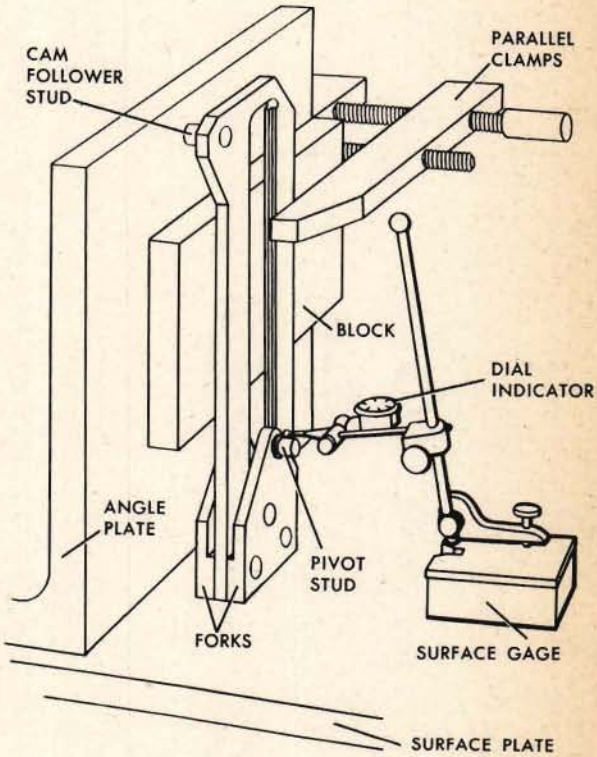
If the pivot studs are badly damaged, the accuracy of the multiplier will be affected and the studs should be replaced. Follow the instructions for removing and riveting studs, pages 77-79. Mount the fork on the arm. Check that the pivot studs are centered over the centerline of the slot in the arm, that they are concentric and that they are at the correct distance from the cam follower stud.



Fit a long block into the slot. Place the block between two parallel bars on a surface plate. With a dial indicator mounted on a surface gage, measure the height of the pivot studs. Invert the bar and arm and again measure the height of the studs. The four measurements should agree within 0.0005 inch. This checks the studs with reference to the centerline of the slot and partially checks their concentricity.

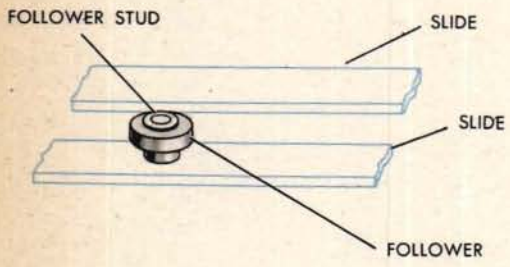
Clamp the arm against an angle plate and measure the height of the studs. The two measurements should agree within 0.0005 inch. This completes the check for the concentricity of the studs.

Refer to the drawings for the distance between the cam follower stud and the pivot studs. With the arm mounted as shown in the lower illustration, use a height gage to measure this distance.



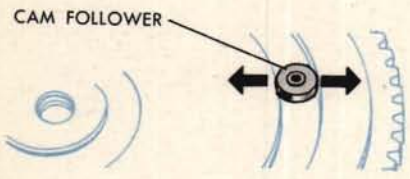
If any one of the requirements is not met, remove the forks, drive out the dowel pins, and reassemble the parts. Shift the forks in the screw clearance holes until all requirements are met. Tighten the screws and redowel with oversize dowels. Check the studs again after doweling.

Checking a cam and its follower



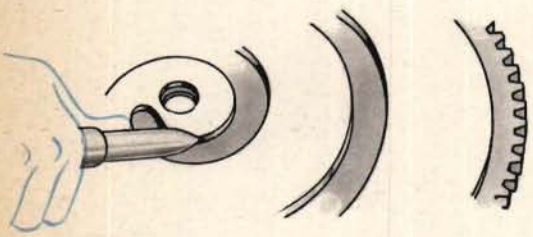
The cam follower should turn freely on the stud without lost motion. Inspect all wearing surfaces of the follower and the stud to be sure they are smooth and polished. Replace either part if its surfaces are scratched or badly worn.

Clean the cam groove with tissue and inspect it for damage and wear. If the sides of the groove are worn deeply or dented, replace the cam.

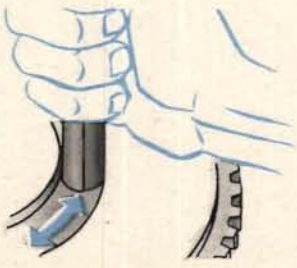


Lost motion between the follower and the groove should not greatly exceed the allowable maximum shown on the assembly drawing. Place the follower in the groove and check lost motion by observing side play along the full length of the groove. Excessive lost motion requires replacing the follower or the cam.

With the follower in the groove, tilt the cam at about 45 degrees. At this angle, the follower should move along the groove. Turn the cam to keep the follower moving. Mark the face of the cam with a pencil to indicate tight spots in the groove.



If the faces of the groove are rough or pitted, burnish or rub metal into the depressions with a hand burnisher before polishing the tight spots.



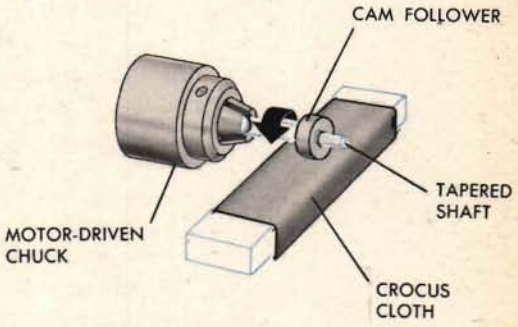
Polish the tight spots in the groove with crocus cloth wrapped around a steel bar. Try the follower often in order to obtain the best possible fit.

Fitting a new follower

Use a fine oilstone to smooth burred or rough edges of the follower. Remove any extremely sharp edges, but leave them square. It is very important not to round or chamfer the edges.

Polish the stud to fit the hole in the follower. The follower should turn smoothly on the stud without lost motion.

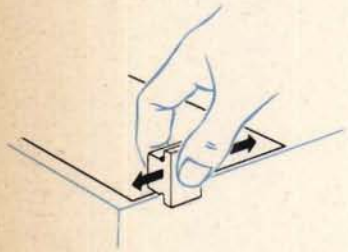
Fit the follower to the widest part of the groove. To reduce the width of the follower, polish it with crocus cloth. Mount it on a slightly tapered shaft held in a slow-speed motor-driven chuck. As the follower turns, polish it against crocus cloth wrapped around a metal block. Try the follower in the groove frequently until it just fits the widest part without lost motion.



Polish down all other parts of the groove to fit the follower, using crocus cloth wrapped around a metal bar. Continue polishing only until the follower will move freely throughout its length without lost motion. Thoroughly clean both the follower and the groove with an approved solvent.

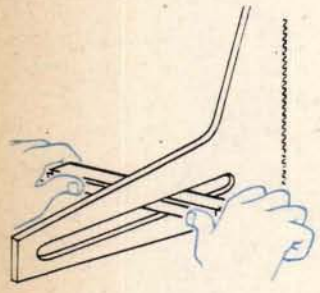
Run the follower back and forth in the groove to burnish off any remaining *slight* high spots. When the fitting has been completed, lubricate the follower and groove with an approved lubricant.

Fitting a rack slide block



Use a fine oilstone to smooth burred or rough edges of the block. Remove any extremely sharp edges, but leave them square. It is very important not to round or chamfer the edges.

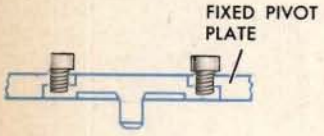
To reduce the width of the block, polish the sides on a piece of crocus cloth placed on a flat surface. Be sure to remove equal amounts from both sides so that the hole remains perfectly centered. Use long, even strokes while holding the block square. Measure it occasionally with a micrometer to be certain that the sides are parallel.



Polish the block until it is a close fit in the widest part of the slot. Polish the rest of the slot to fit the block, using crocus cloth wrapped once around a steel bar. Be sure to keep the sides of the slot parallel and flat.

Before trying the block in the slot, thoroughly wash, dry, and lubricate them both. The fit is correct when the block can be moved the full length of the slot. Move the block back and forth by hand until it travels smoothly from one end to the other. Finally, wash the block and slot again with an approved solvent, and apply an approved lubricant to the slot.

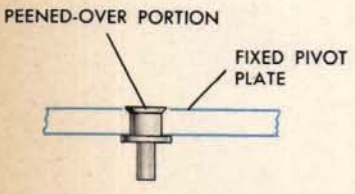
Replacing a fixed pivot stud



SCREW-FASTENED STUD

Fixed pivot studs are either riveted to the fixed pivot plate, using one end of the stud as a rivet, or fastened to the plate with screws.

A screw-fastened stud can be removed by taking out the screws.



RIVETED STUD

A riveted stud can be removed by drilling into the stud with a center drill until the peened-over portion of the stud is removed. Be sure to use a support under the stud to avoid bending or distorting the plate. For a detailed explanation of removing and replacing parts which are riveted in this way, see pages 77-79.

If necessary, polish the new stud so that it will move freely in the hole in the slide block with a minimum of lost motion. Adjust the distance between the stud and the center of the pivot disk during final assembly of the unit.

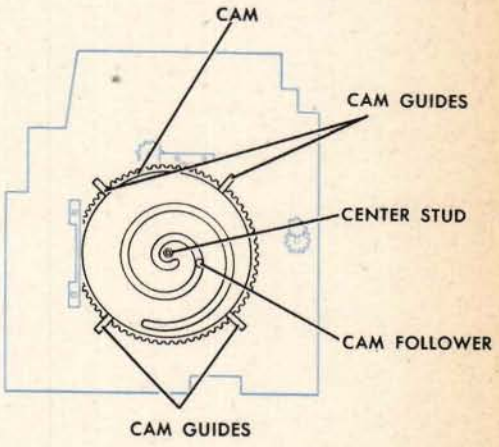
Reassembling the single cam unit

Wash all parts with an approved solvent and dry them before beginning to reassemble the unit. Lubricate each piece before assembling it. After mounting each part, check for lost motion and smoothness of operation.

1 Replace the cam on the center stud.

2 Replace the four cam guides.

3 Place the follower in the cam groove.

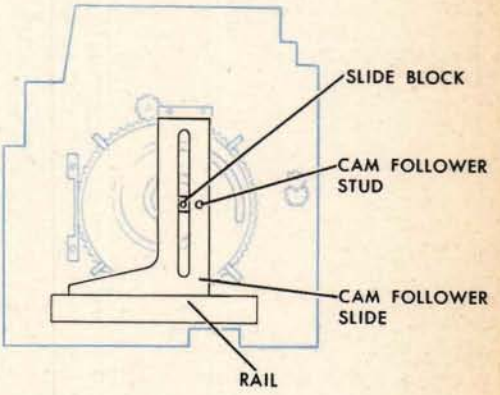


4 Move the cam follower slide onto its rail.

5 Mount the slide and rail on the plate.

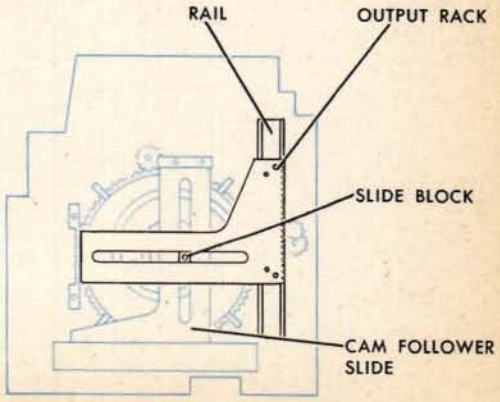
6 Turn the cam and move the slide until the cam follower stud drops into the follower. *Caution: Be careful not to damage the cam groove with the sharp edge of the stud.*

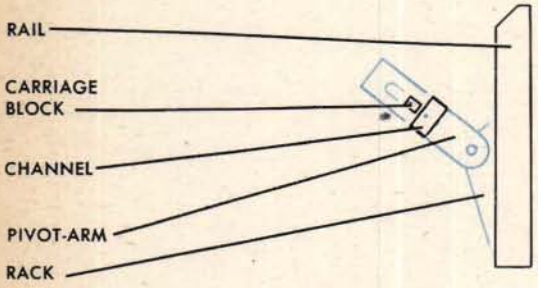
7 Place the slide block in the slide slot.



8 Move the output rack onto its rail and fasten the rail in place.

9 Place the slide block in its slot and position it over the lower slide block.

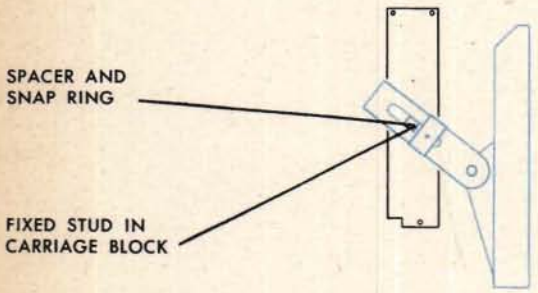




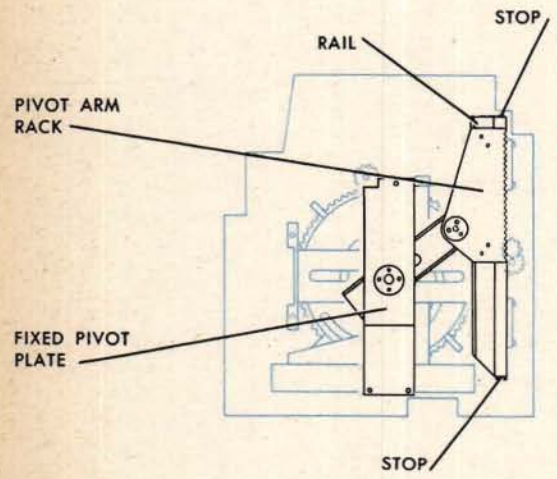
10 Slide the pivot-arm rack into the rail.

11 Slide the channel onto the pivot arm.

12 Place the carriage block in the pivot-arm slot.



13 Insert the fixed stud into the carriage block. If a spacer and snap ring were used as a retainer, replace them on the fixed stud at this time.

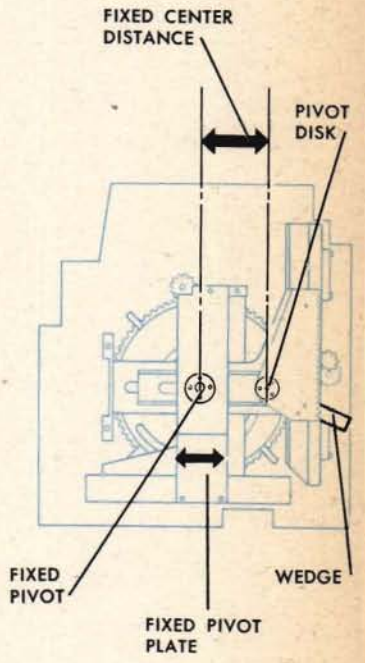


14 Lift the plate and pivot-arm assembly and fit it in place on the multiplier assembly, inserting the channel stud through both slide blocks. Secure the plate and rail to the main plate.

15 Replace the stops on the ends of the rail.

Setting the fixed center distance

To facilitate the measurement of the fixed center distance, small holes of accurate diameter and location are usually provided in the center of the multiplier pivot disk and in the fixed pivot. When two pins of the proper diameter are placed in these holes, the center distance can be measured with a vernier caliper. Consult the assembly drawing for the required distance between the fixed pivot and the line of travel of the center of the pivot disk. When making this measurement, the slot in the pivot arm should be in line with the slot in the output rack. A bakelite wedge may be used to hold the pivot-arm rack in this position.



If a concentric pivot stud is used, reposition the bridge to adjust the distance. Remove the dowels in the bridge, reposition the bridge to establish the correct distance, and redowel the bridge with oversize dowels.

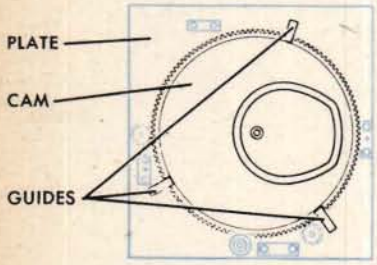
If an eccentric pivot stud is used, turn it to the correct position. Do not forget to stake a small amount of metal into the screwdriver slot to hold the stud in position.

Remove the bakelite wedge. Move the cam and the input rack through their full travel to check for smoothness and lost motion.

Bench checking the unit

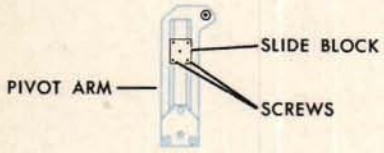
1. Check the assembly of the unit against the assembly drawing.
2. All eccentric studs should have been staked to hold them in position.
3. The cam follower should travel freely and without lost motion from one end of the cam groove to the other.
4. Lost motion between slides and rails should be at a minimum. The maximum lost motion is indicated on the assembly drawing.
5. The distance between the fixed pivot and the input-arm pivot must be within the limits shown on the assembly drawing.
6. The pivot-arm rack must move freely through its full travel.

Reassembling the double cam unit

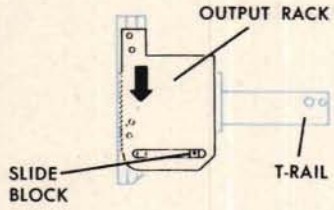


Wash all parts with an approved solvent and dry them before beginning to reassemble the unit. Lubricate each piece before assembling it. After mounting each part, check for lost motion and smoothness of operation.

1 Replace each cam on its plate. Replace the guides.

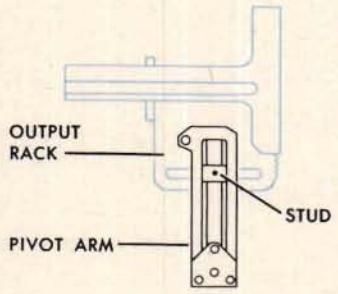


2 Replace the slide block in the pivot arm. Stake the flat-head screws.

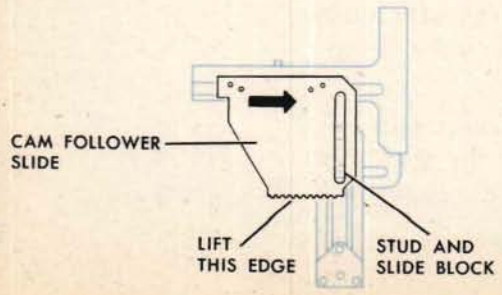


3 Slide the output rack onto the T-shaped rail.

4 Turn the output rack and rail assembly over and replace the slide block in the rack slot.



5 Hold the pivot arm over the output rack with the multiplier stud centered over the slide block in the rack. Lower the pivot arm into position so that the stud goes into the output-rack slide block.



6 Replace the slide block of the cam follower slide on the multiplier stud.

7 Fit the cam follower slide into its rail, raising the end to clear the stud.

8 Turn the assembly over and position it carefully over the lower plate. Support the assembly above the plate and turn the lower cam until the cam follower in the lower rack drops into the cam groove.

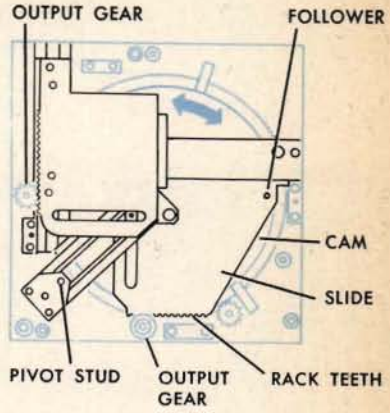
9 Lower the assembly into place. If an intermediate output is taken from the square-cam follower slide, carefully mesh the rack teeth on the slide with the mating gear. Guide the pivot stud on the fork of the pivot arm into its bearing in the lower plate.

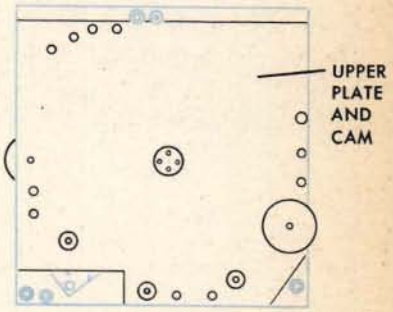
10 Check the assembled parts for freedom of movement before fastening the rail.

11 Position the upper plate and cam over the assembly. Turn the upper cam and move the pivot arm until the cam follower in the pivot arm lines up with the cam groove. Lower the top plate and the cam into position.

12 Turn both cams to check for smoothness of operation before replacing the screws in the top plate.

Recheck the unit for smoothness of operation and correct fit by turning both cams through their full travel.





Bench checking the unit

1 Check the assembly of the unit against the assembly drawing.

2 There should be no binding or sticking throughout the full travel of both cams.

3 Lost motion between racks and rails should be reduced to a minimum. The allowable maximum is indicated on the assembly drawing.

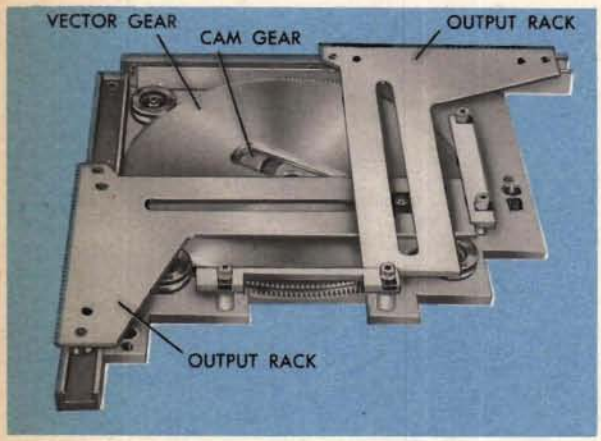
4 Lost motion between followers and cams and between rack slots and pivot studs should be reduced to a minimum. The allowable maximum is indicated on the assembly drawing.

5 Both input gears should mesh properly with their cams throughout the full travel of the cams.

6 When the lower cam follower is at the inner limit of the cam groove, there should be no motion of the output rack as the upper cam is turned through its full travel. The allowable maximum is indicated on the assembly drawing.

7 Check the effect of upper cam positioning on movement of the output rack, as indicated on the assembly drawing.

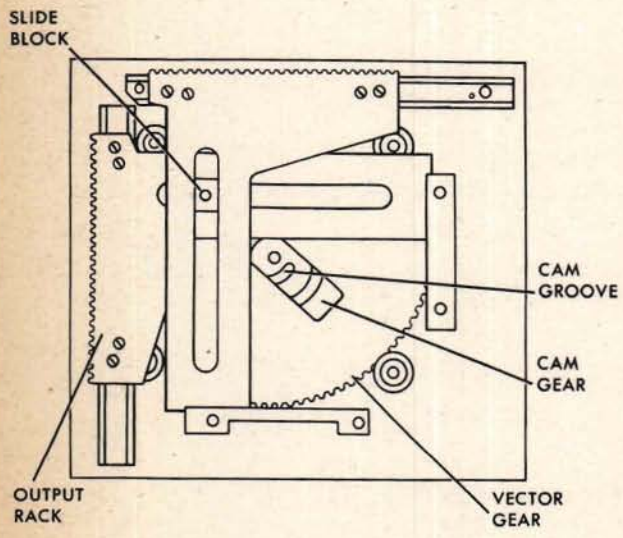
THE CAM TYPE COMPONENT SOLVER



A cam type component solver is usually mounted on a separate base plate, with the output and input gears at the sides of the unit. The *inputs* are carried by the cam gear and the vector gear. The *outputs* are carried by the two racks.

In order to remove the cam type component solver, other units and gearing groups often must be removed first. For this reason, the exact source of the trouble in the unit should be located before removal is considered. If the unit must be removed for repair, consult the instrument OP for instructions.

Typical symptoms



If a test analysis and unit check test indicate that a cam type component solver is not operating normally, look for one or more of the following typical symptoms:

JAMMING: The cam, the vector gear, or one or both of the racks cannot be moved by hand.

STICKING: The cam, vector gear, or racks move sluggishly, or resist moving past certain points.

EXCESSIVE LOST MOTION: There is too much play between a rack and rail, the cam follower and cam groove, or the vector gear is loose in its guide rollers.

SLIPPING: Moving the cam and the vector gear results in only intermittent movement or in no movement of the output racks.

Locating the cause

Cam: jamming or sticking

The cam may be jammed at either end of its travel because the follower has driven against the end of the groove and bent the follower stud. To replace a bent follower stud it is necessary to disassemble the unit. This type of jamming is usually caused by an improperly adjusted limit stop in the cam input shaft line. The instrument OP gives directions for the proper adjustment of this limit stop.

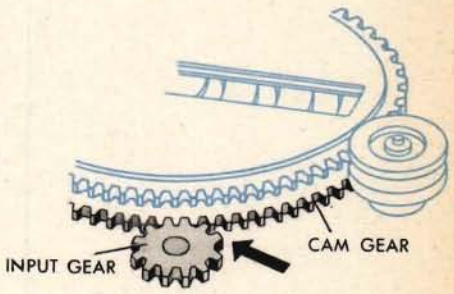
A cam may jam or stick within its normal travel because of damaged or dirty teeth on the cam rim, a sticking guide roller, a bent follower stud, or a cam follower locked in its groove because of damage or dirt.

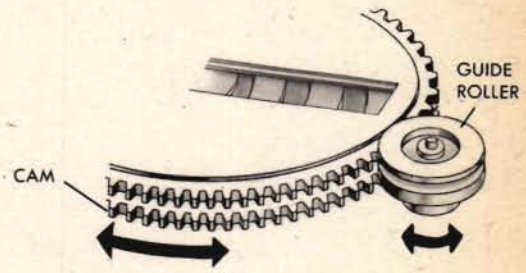
To check for jamming or sticking of the cam rim, inspect the mesh between the cam and its meshing gear. Damaged or dirty teeth usually can be repaired in place.

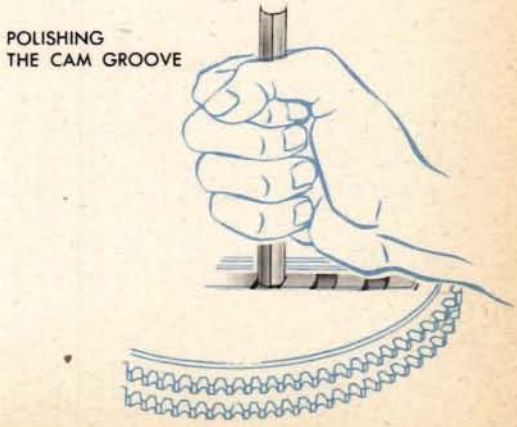
To check for a sticking guide roller, turn the cam through its travel several times and watch each of the four guide rollers in turn. Sticking may occur once for each revolution of the cam or of a guide roller. Sticking caused by a small burr or nick on the cam or a guide roller can often be repaired in place by filing or polishing. If the cam of a follower is damaged enough to require replacement, the unit must be disassembled.

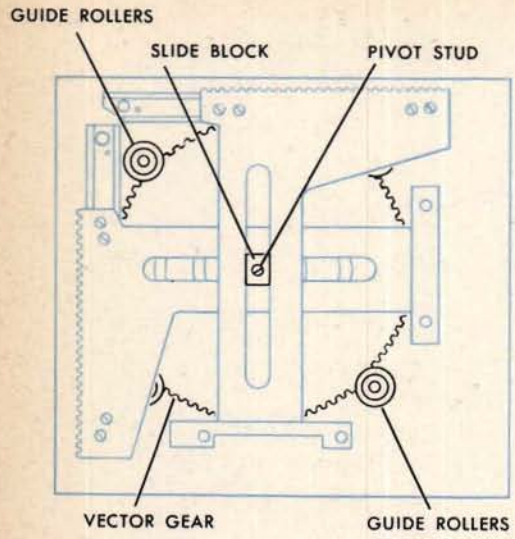
To check for a sticking cam follower, turn the cam again and observe the position of the follower in the cam groove. If the follower always sticks at the same place in the groove, mark the spot and inspect the groove carefully for damage. Wipe the groove clean with tissue, remove embedded particles, and polish the tight or rough spot. Be careful to avoid enlarging the groove. Thoroughly clean and lubricate the groove before turning the cam to check for smoothness.

If sticking does not always occur at the same place, the trouble may be caused by the cam follower or the cam follower stud. The unit must be disassembled to repair these parts.







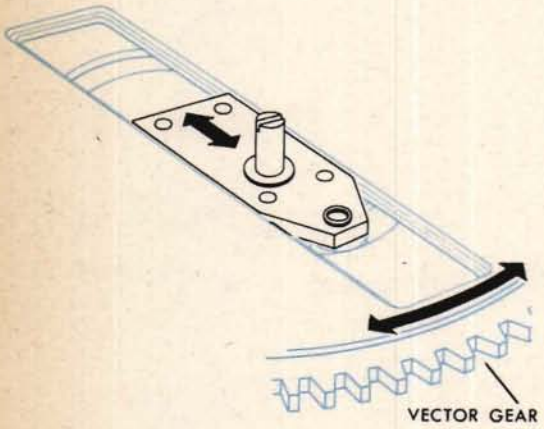


Vector gear: jamming or sticking

A vector gear may jam or stick because of damaged or dirty gear teeth or guide rollers. Dirt, burrs, or nicks in the gear teeth can sometimes be removed without disassembling the unit. If the vector gear sticks in the guide rollers, the roller assemblies can sometimes be washed and lubricated in place. If the guide rollers must be removed, the unit should be disassembled.

The vector gear may not turn or may turn sluggishly because the slide blocks jam or stick on the pivot stud. Inspect these blocks for jamming or sticking. The block in the slot of the outside rack can be repaired without disassembling the entire unit.

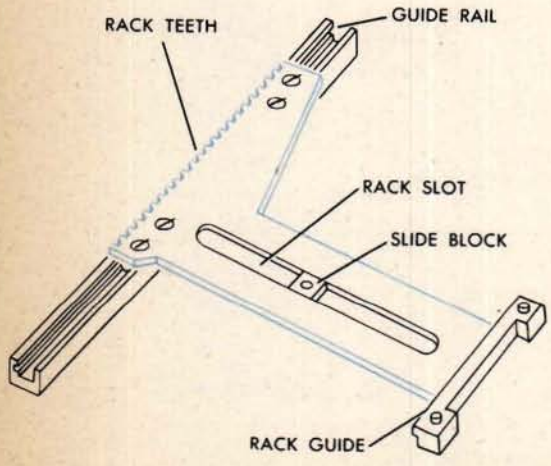
If the carriage block can be moved when the vector gear is jammed, the trouble may be due to dirty or damaged gear teeth. Often the vector gear can be moved from its jammed position by hand and cleaned and lubricated without disassembling the unit. Turn the vector gear to inspect the teeth for dirt or damage.



Racks: jamming or sticking

A rack may jam or stick because of a dirty or damaged rack guide, guide rail, rack roller, rack slot, sliding block, or defective gear teeth. Slight damage may be repaired and the parts cleaned and lubricated without disassembling the unit. Improper positioning of the rollers may cause them to jam or stick in the rails, or make too tight a mesh between the rack and pinion. Shake the rack to check lost motion between the roller and rail. Usually a block which sticks slightly in a rack slot can be restored to normal operation by cleaning and lubricating the sliding surfaces and running the parts back and forth to work them in smoothly. Disassemble the unit for repair only if it sticks enough to cause serious errors in the operation of the instrument.

If neither rack can be moved and the cause is not found in the parts in contact with the racks, the cause may be a jammed cam, carriage block, or vector gear.



Excessive lost motion

Excessive lost motion of the racks may be caused by worn parts or a loose roller stud. Shake each rack to check that the lost motion does not exceed the limits given on the assembly drawing. If excessive lost motion is detected, reposition the rollers which are located away from the rack teeth.

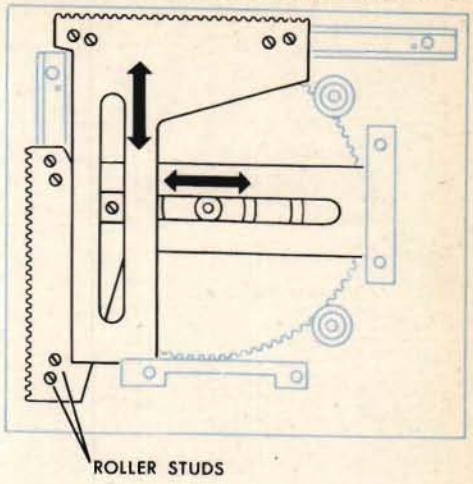
Lost motion between both racks and the cam and the vector gear can be checked in one operation. Position the cam and the vector gear at various points within their travel and shake both racks at each position. Lost motion may be caused by a worn slide block or slot, or by a worn follower in the cam groove. To eliminate such lost motion, the unit must be disassembled and the worn parts replaced.

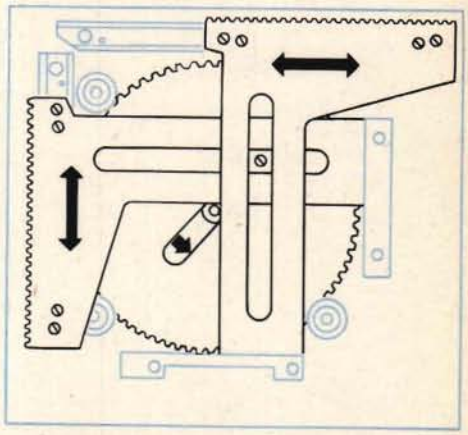
Shake the vector gear to check for side play. Any noticeable side play is caused by improper adjustment of the four guide rollers. To reposition the rollers, the unit should be disassembled and the eccentric studs repositioned. Excessive side play should be eliminated at the same time the vector gear is centered.

Slipping

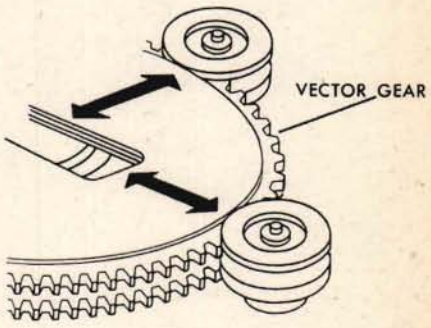
If moving the input cam and the vector gear results in only intermittent movement or in no movement of the output racks, the trouble may be caused by stripped rack teeth or a broken pivot or follower stud. A rack with stripped teeth should be replaced. To inspect for a loose or sheared pivot or follower stud, move the racks through their full travel by turning the cam and the vector gear *alternately*. If either rack does not move smoothly, the unit should be disassembled to repair or replace the faulty stud.

SHAKING THE RACKS TO CHECK FOR LOST MOTION

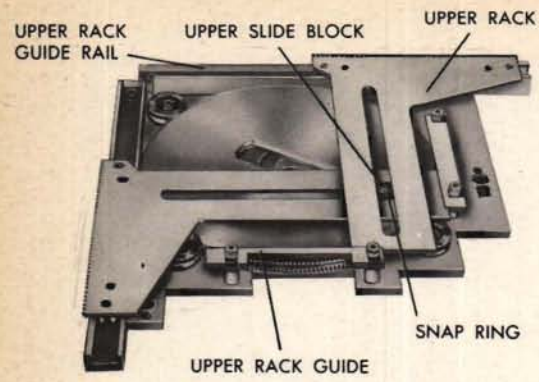


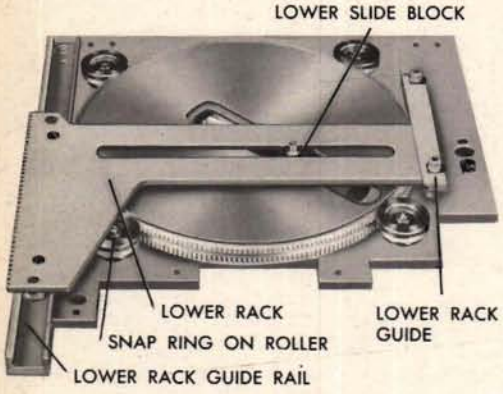


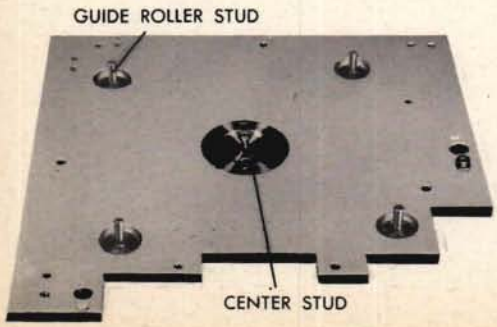
POSITIONING CAM AND VECTOR GEAR AT VARIOUS POINTS AND SHAKING THE RACKS



CHECKING THE VECTOR GEAR SIDE PLAY







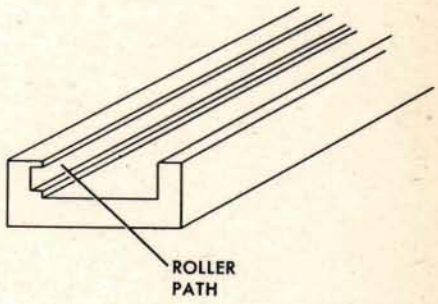
Disassembling the unit

1. Remove the snap ring and spacer from the slide block stud.
2. Remove the screws holding the upper rack guide and guide rail. Lift off the guide, rack, and rail together.
3. Lift off the upper slide block. Keep it with its rack.
4. Remove the lower rack together with its guide rail and rack guide.
5. Lift off the lower slide block. Keep it with its rack.
6. Remove the snap rings from the four support rollers.
7. Mark each stud and its roller to simplify reassembly.
8. Lift off the four rollers and the vector gear, being very careful not to cock the gear. This operation requires two men.
9. Lift out the cam follower.
10. Remove the cam. Usually the bearing is held by a retainer on the under side of the cam, but it is fastened in different ways on different units. Study the assembly drawing before attempting to remove the cam.
11. Turn the vector gear over and remove the four flat-head screws which hold the retainer plate to the carriage block. Lift off the carriage block and retainer plate.
12. Remove the center stud.
13. Do not remove the four guide roller studs unless the vector gear is not centered or has excessive side play.

Repairing the parts

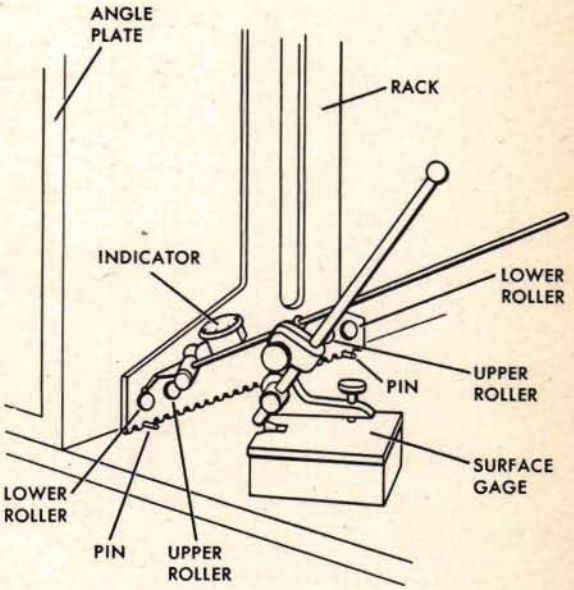
Repairing a rail

First use tissue to clean the roller path in the rail. Carefully remove any embedded foreign material. Then check the straightness of the roller path, and if necessary polish rough or high spots with crocus cloth, trying the rack in the rail frequently until a good fit is obtained. After completing this work, clean the parts thoroughly with solvent and lubricate them.



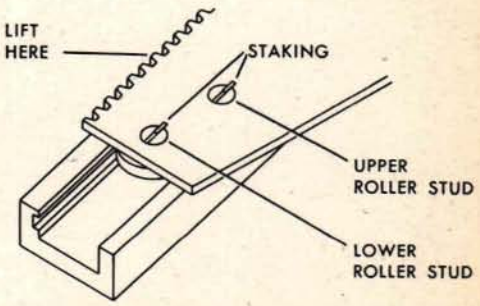
Adjusting the rack rollers

The lower rollers position the pitch line of the rack in relation to its meshing gear. These rollers affect the alignment of the rack slots as well as the mesh of the rack and the gear. Remove the rack and mount it against an angle plate on a surface plate. Support the rack under the teeth, using two identical pins between 0.070 and 0.075 inch in diameter. Place a pin under each end of the rack. With a surface gage and a dial indicator, measure the height of the lower rollers. The heights of these rollers must agree with the assembly drawing and be within 0.0002 inch of each other.



The upper rollers control the play between the rack and its rail. The play should not exceed 0.0005 inch. A strip of feeler gage material (0.001 inch) can be used to check the clearance between the roller and the roller path.

To position the rollers, turn the roller studs with a screw driver. Then stake a small amount of metal into the screw driver slots of the stud heads.

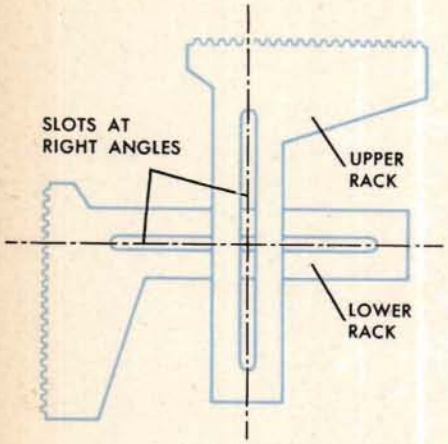


The rollers should be free enough in the rail for the rack to drop back of its own weight if it is raised slightly with one finger.

For an explanation of the method of removing and replacing a riveted stud, see page 76.

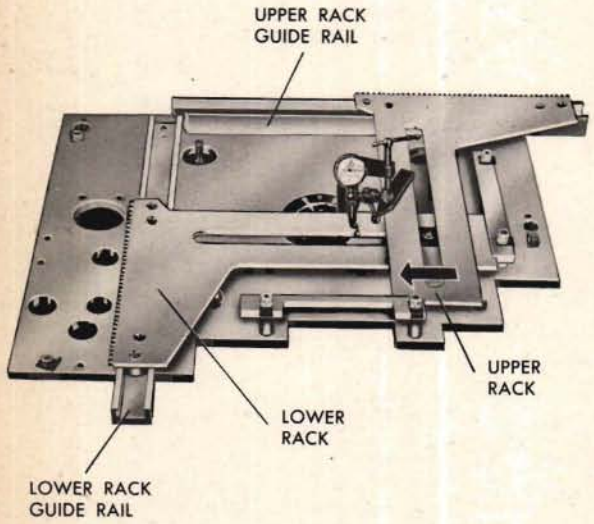
Squaring the racks

The slots in the upper and lower racks must be at right angles to each other.



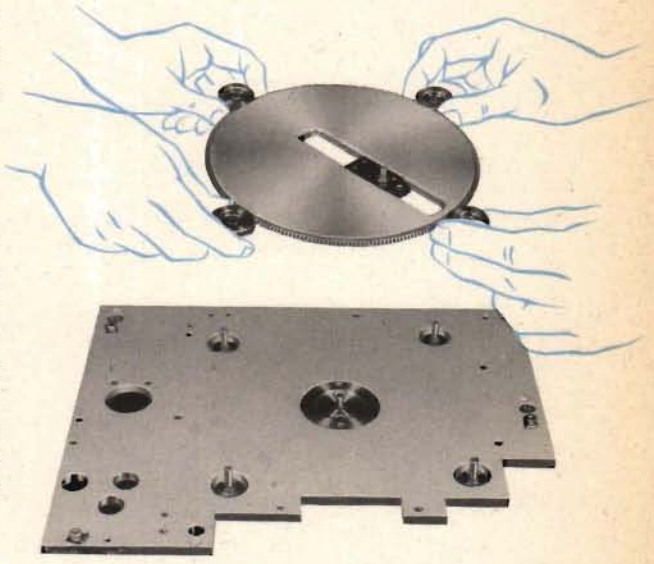
Reassemble on the plate the two racks, their rails and guides. The vector gear and cam gear should not be installed for this operation. Wedge the lower rack to prevent it from moving.

Mount a dial indicator firmly on the top rack with its point on one face of the lower rack slot. Move the upper rack through its full travel and observe the reading as the point of the indicator moves along the face of the slot in the lower rack. If the total reading exceeds 0.001 inch, check the setting of the lower rollers on the lower rack as instructed on page 251. It is advisable to check the lower rollers of the upper rack at the same time. Replace the two racks and repeat the check for squareness. If the indicator reading still exceeds 0.001 inch, reposition one of the rails. To do this, first drive the dowels out of the rail. Then replace the rail and its rack and repeat the check for squareness. If the indicator reading its still excessive, loosen the screws holding the rail, and move the rail within the clearance of its screw holes until a reading of 0.001 inch or less is obtained. Then tighten the screws and redowel the rail with oversize dowels.



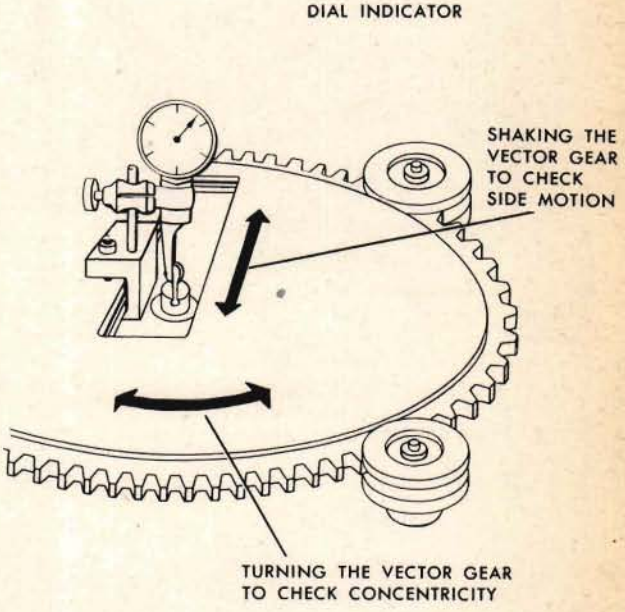
Centering the vector gear

Excessive side play of the vector gear should be eliminated at the same time that the vector gear is centered, so that the vector gear is always kept concentric with the center stud.



First remove the vector gear and the guide rollers. To prevent bending the vector gear, two men are needed to lift the four guide rollers evenly. Remove the cam gear. Unscrew the nuts which secure the roller studs to the plate, remove the studs, and tap out the dowels which position the studs. Replace each stud and hold it loosely in place with the nut. Mount the vector gear and the four guide rollers.

Now mount an indicator firmly on the vector gear with its point against the side of the center stud. Two adjustments are to be made at the same time: The vector gear is to be centered and the guide rollers repositioned to reduce side play. Turn the vector gear one revolution and watch the dial for variations in readings. Turn the eccentric studs to reposition the rollers. Turn the vector gear one revolution and check the variations of dial readings again. When the indicator shows the minimum possible variation, the vector gear should at the same time turn freely but with side play within the limits given on the assembly drawing.



Tighten and stake the nuts holding the studs and remove the rollers and the vector gear. Redowel the studs with oversize dowels.

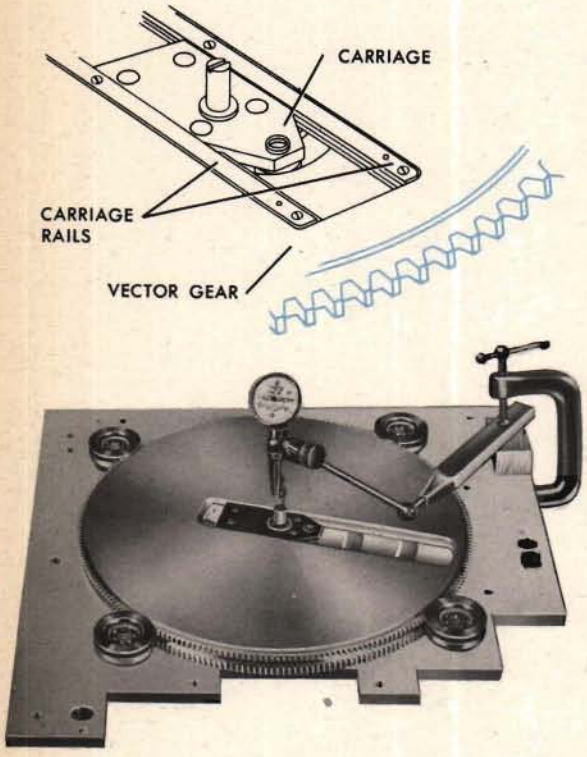
Reducing lost motion between the vector gear and its spur gear

If there is excessive lost motion between the vector gear and the spur gear, the spur gear should be repositioned. *Never* move the vector gear to reduce lost motion, because doing so will disturb the concentricity of the cam and vector gear.

Adjusting the carriage block and carriage rails

On large component solvers, adjustable rails are used to reduce lost motion of the carriage block. To adjust the carriage block, first remove the rails and drive out the dowels. Replace the rails and carriage block on the vector gear and adjust the screws holding the rails until the carriage block can be moved through its full travel without lost motion.

The rails cannot yet be redoweled because adjusting them usually disturbs the pivot stud.



MOUNTING THE VECTOR GEAR ASSEMBLY ON THE PLATE AND CENTERING THE CARRIAGE BLOCK

Centering a concentric pivot stud

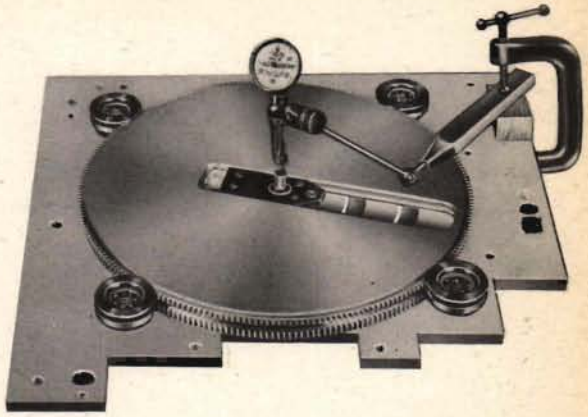
To center the concentric pivot stud in the carriage block of a large component solver, first center the vector gear and eliminate side play according to the instructions on the previous page. Then position the pivot stud by moving the carriage along its rails to the center of the vector gear. Mount a dial indicator on the plate, with the point against the side of the pivot stud. Turn the vector gear one revolution and observe the variation in readings. Reposition the rails until a minimum variation of dial readings is obtained. If necessary, continue repositioning the carriage block and moving the rails until the variation of indicator readings is within the limit allowed by the assembly drawing. When moving the rails, be careful to maintain the fit of the carriage block throughout its travel.

When a final adjustment has been made, tighten the rail screws, remove the vector gear, and redowel the rails with oversize dowels. In fitting the dowels, be careful not to warp the rail.

Centering an eccentric pivot stud

To center the eccentric pivot stud on the carriage block of a small component solver, first center the vector gear and eliminate side play according to the instructions on page 253. The cam and vector gear will then be concentric. Turn the cam until the pivot stud appears to be centered. Now mount an indicator on the plate with its point against the side of the stud and at right angles to the slot. Hold the cam and the vector gear together and turn them 180°. Observe the difference in dial readings. If the difference exceeds the allowable maximum shown on the assembly drawing, turn the stud, being careful not to burr the slot with the screw driver. Reposition the carriage block and repeat the test until excessive lost motion is within the proper limit. Stake the stud to hold it in its new position. Use care in riveting and staking the stud to avoid warping or distorting the carriage block.

For a detailed explanation of removing and replacing parts which are riveted in this way, see pages 77-79



CENTERING AN ECCENTRIC PIVOT STUD

Fitting a new slide block

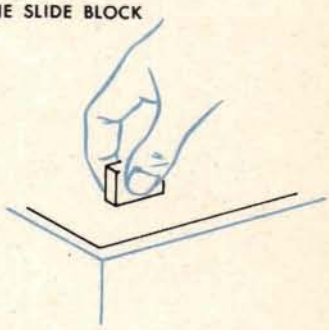
Use a fine oilstone to smooth burred and rough edges of the block. Remove any extremely sharp edges but leave them square. It is very important not to round or chamfer the edges.

To reduce the width of the block, polish the sides on a piece of crocus cloth placed on a flat surface, using long, even strokes while holding the block square. Be sure to remove equal amounts from each side, so that the hole remains perfectly centered. Measure the block occasionally with a micrometer to be certain that the sides are parallel.

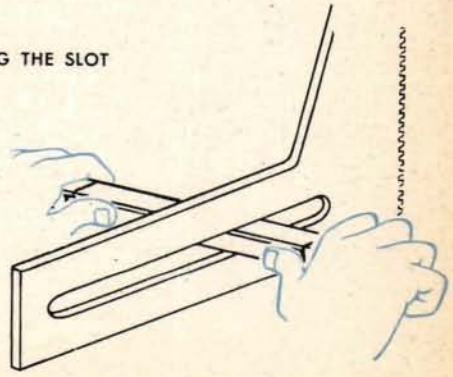
Polish the block until it fits closely in the widest portion of the slot. Polish the rest of the slot to fit the block, using crocus cloth wrapped once around a steel bar. Be sure to keep the slot sides square and flat.

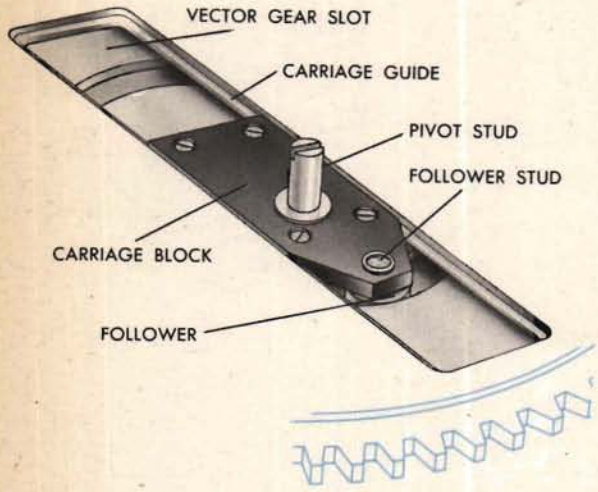
Before trying the block in the slot, thoroughly wash, dry, and lubricate both parts. The fit is correct when the block can be moved the full length of the slot. Move the block back and forth by hand until it travels smoothly from one end to the other. Finally, wash the slot and block again, and lubricate the slot.

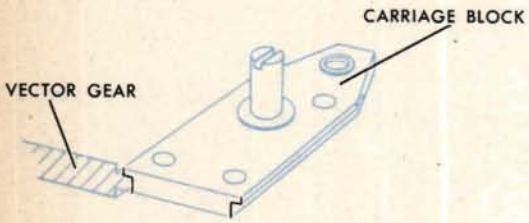
POLISHING THE SLIDE BLOCK

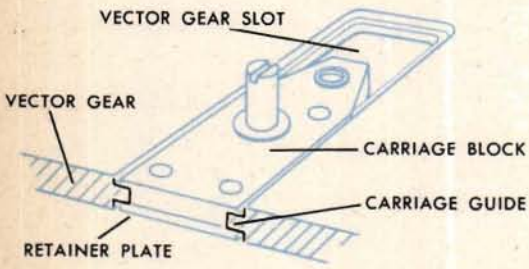


POLISHING THE SLOT









Fitting a new carriage assembly

In fitting a new carriage assembly, a new pivot stud must be used. First fit the carriage block between the carriage guides in the vector gear slot. Use a fine oilstone to smooth burred and rough edges of the block. Remove any extremely sharp edges but leave them square. It is very important not to round or chamfer the edges. Try the block on the carriage guides. If necessary, polish the sides of the block on crocus cloth until it fits without lost motion in the widest part of the space between the carriage guides. Remove equal amounts from each side so that the stud hole remains centered. During this operation do not remove material from any surface of the block except the sides which fit between the guides. Measure the block occasionally with a micrometer to be certain that the sides are parallel.

Polish the inner faces of the carriage guides with crocus cloth backed up by a steel bar until the block can be moved freely through the full length of the vector gear slot. Keep the sides square and flat. Clean the guides and the block thoroughly each time before trying them together. Apply a little lubricant, and move the block back and forth by hand until it travels smoothly from one end to the other.

When a new retainer plate is to be fitted, it is mounted with the carriage block on the guides in the vector gear slot. Tighten each of the four screws a little at a time. Each time the screws are tightened, slide the assembly back and forth on the guides.

If the carriage slots are too narrow, the carriage assembly will clamp tightly on the carriage guides when the screws are tightened. Remove the carriage block and polish the surfaces which ride on the guides until the assembly can be moved over the thinnest portion of the guides. Then, if necessary, polish the upper faces of the guides to fit the carriage slots.

If the carriage slots are too wide, polish the bottom of the block to reduce their width. Wash, dry, and grease the parts, reassemble them, and run the assembly back and forth in the slot by hand.

Checking a cam and its follower

The cam follower should turn freely on the stud without lost motion. Inspect all wearing surfaces of the follower and the stud to be sure they are smooth and polished. Replace either part if its surfaces are scratched or badly worn.

Clean the cam groove with tissue and inspect it for damage and wear. If the sides of the groove are worn deeply or dented, replace the cam, if a replacement is available. If the groove is worn fairly evenly, try an oversize roller.

Lost motion between the follower and the groove should not greatly exceed the allowable maximum shown on the assembly drawing. Place the follower in the groove and check lost motion by observing side play along the full length of the groove. Excessive lost motion requires replacing either the follower or the cam.

With the follower in the groove, tilt the cam at about 45°. At this angle, the follower should move along the groove. Turn the cam to keep the follower moving. Mark the face of the cam with a pencil to indicate tight spots in the groove.

If the faces of the groove are rough or pitted, burnish or rub metal into the depressions with a hand burnisher before polishing the tight spots.

Polish the tight spots in the groove with crocus cloth wrapped around a steel bar. Try the follower often in order to obtain the best possible fit.

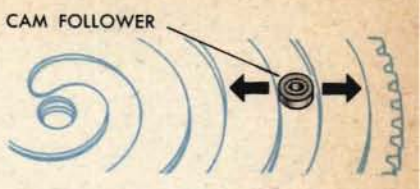
Fitting a new follower

Use a fine oilstone to smooth burred or rough edges of the follower. Remove any extremely sharp edges, but leave them square. It is very important not to round or chamfer the edges.

Polish the stud to fit the hole in the follower. The follower should turn smoothly on the stud without lost motion.

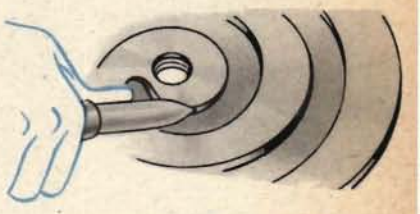
Fit the follower to the widest part of the groove. To reduce the width of the follower, polish it with crocus cloth. Mount it on a slightly tapered shaft held in a slow-speed motor-driven chuck. As the follower turns, polish it against crocus cloth wrapped around a metal block. Try the follower in the groove frequently until it just fits the widest part without lost motion.

Polish down all other parts of the groove to fit the follower, using crocus cloth wrapped around a metal bar. Continue polishing only until the follower will move freely throughout its length without lost motion. Thoroughly clean both the follower and the groove and lubricate them. Run the roller back and forth in the groove by hand until it will slide through its full travel when the cam is tilted at an angle of 45°.

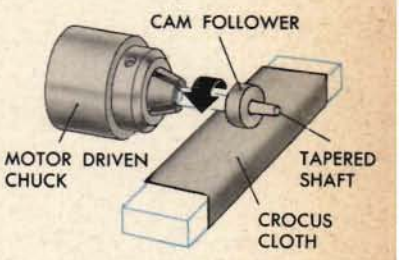


CHECKING FOLLOWER SIDE MOTION

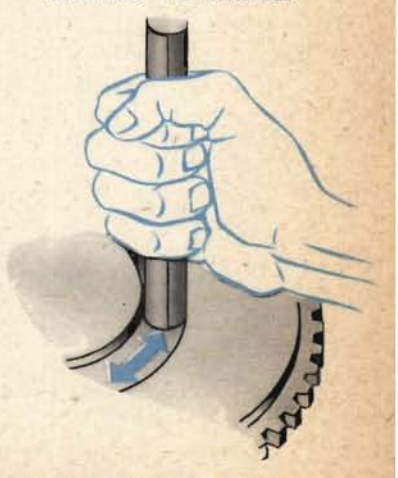
CHECKING FREEDOM OF FOLLOWER TRAVEL



BURNISHING ROUGH SPOTS



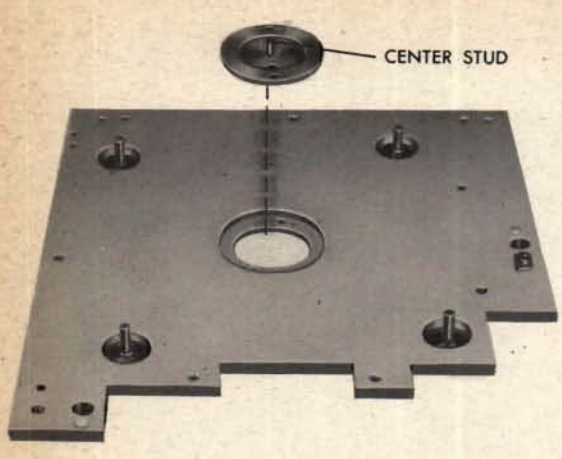
POLISHING THE FOLLOWER



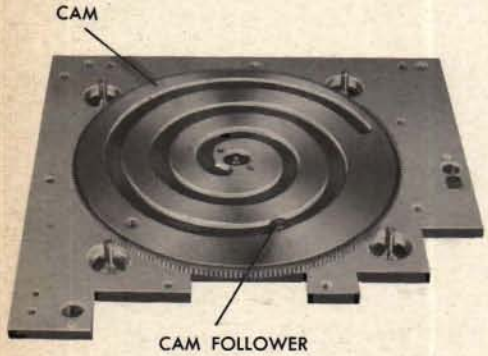
POLISHING TIGHT OR ROUGH SPOTS

Reassembling the unit

Wash and dry all the parts, and lubricate each part as it is replaced. Use a little grease on all slots, grooves, slide blocks, pivot studs, rack guides, guide rails, and the carriage block. Use light machine oil in the bearings and rollers.

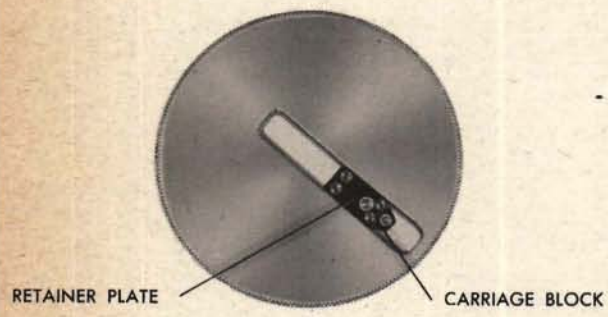


1 Replace the center stud.



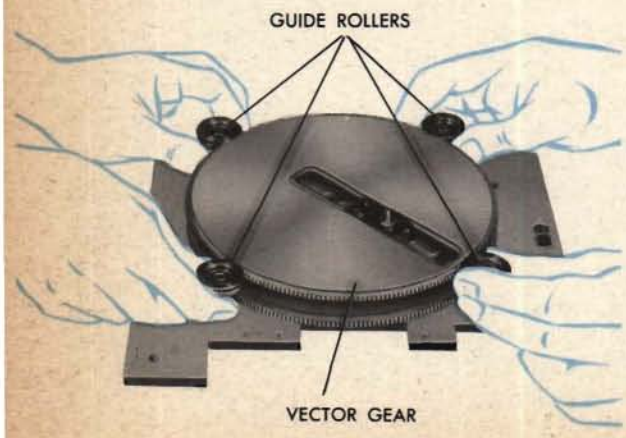
2 Replace the cam on its stud.

3 Place the cam follower in the cam groove.



4 Place the carriage block in the vector gear slot.

5 Fasten the retainer plate to the carriage block and stake metal from the screws into the indentations in the hardened plate.



6 Position the four rollers on the outside of the vector gear and place all four rollers on their studs. This job requires two men to avoid cocking or binding the vector gear.

7 Replace the snap rings on the roller studs.

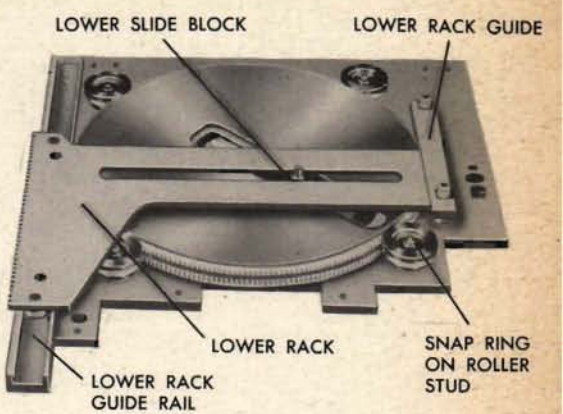
8 Replace the lower rack guide and guide rail.

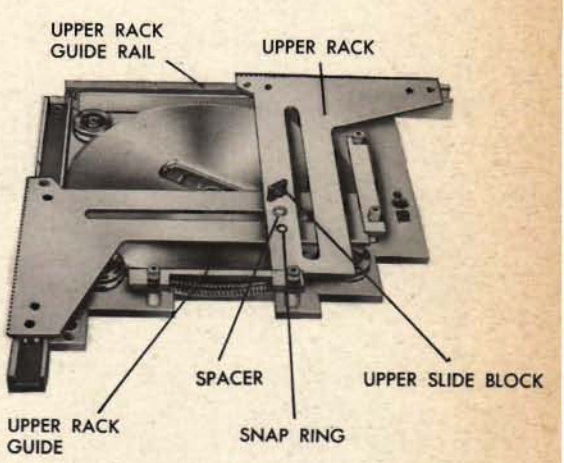
9 Place the lower slide block on the pivot stud.

10 Replace the upper-rack guide rail and rack guide.

11 Place the upper slide block on the pivot stud.

12 Replace the spacer and snap ring on the pivot stud.





Bench checking the unit

1 Check the assembly of the unit against the assembly drawing.

2 Check that the carriage block pivot stud may be brought to a zero point where there is no motion of the racks when the vector gear and cam are turned together. The maximum allowable rack movement at the zero point is shown on the assembly drawing.

3 With the cam follower at the outer limit of the cam groove, turn the vector gear through its full travel. The racks should move freely and smoothly through their full travel without excessive lost motion.

4 Using an indicator, check to be sure that the slots in the racks have been exactly squared.

5 Using an indicator, check that the cam gear and vector gear are concentric on their pivots. The assembly drawing gives the allowable variation of indicator readings.

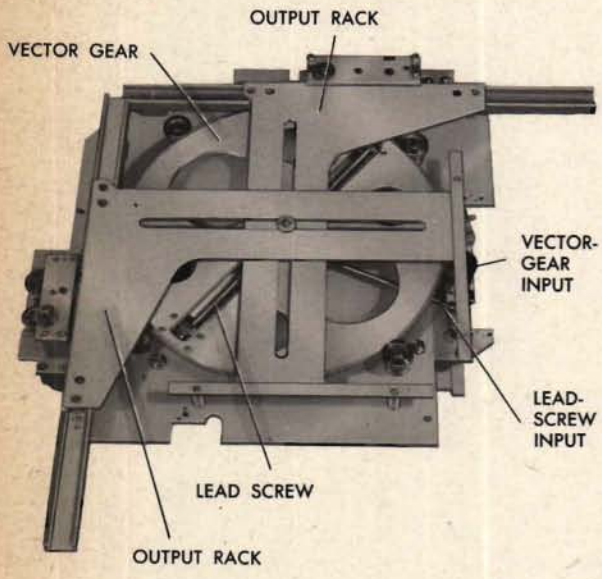
6 Check that all the eccentric roller studs have been doweled and that their nuts have been staked.

7 Check that lost motion between racks and rails is within the limits shown on the assembly drawing.

THE SCREW TYPE COMPONENT SOLVER

A screw type component solver either shares a plate with gearing groups and other units or is mounted on a separate base plate which is fastened to a larger plate. The inputs go to the lead screw and the vector gear. The outputs come from the two racks.

If the unit must be removed for repair, consult the instrument OP for instructions.



Typical symptoms

If a test analysis and a unit check test indicate that a screw type component solver is not operating normally, look for one or more of the following typical symptoms:

JAMMING: The lead screw, the vector gear, or one or both of the racks cannot be moved by hand.

STICKING: The vector gear or the racks move sluggishly or resist moving past certain points.

EXCESSIVE LOST MOTION: Too much play exists between a rack and rail, between the carriage block and lead screw, or between the carriage block and its slot; or the vector gear has too much side play. The lead screw may have too much end play between its hangers.

SLIPPING: Moving the lead-screw input or the vector gear results in only intermittent movement, or in no movement of the output racks.

Locating the cause

Lead screw: jamming or sticking

The lead screw may jam or stick because of a bent lead screw, dirty or damaged lead screw threads, a damaged slot in the vector gear or trouble in the shaft lines within the unit.

If the carriage is jammed at either end of the lead screw, try to move it out of its position by turning the lead-screw input gear. This type of jamming is usually caused by an incorrect limit-stop adjustment in the lead-screw input shaft line. The instrument OP gives directions for adjusting this limit stop.

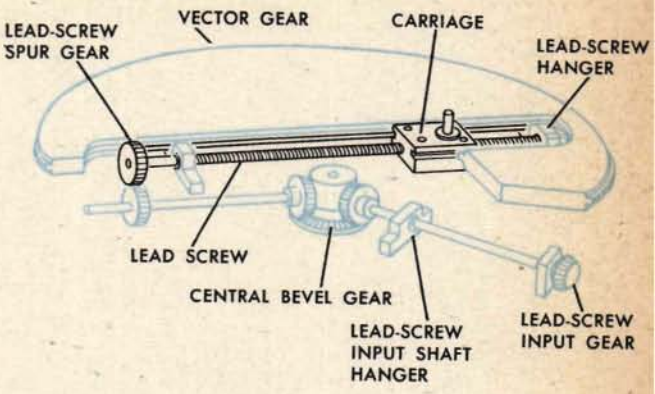
If the carriage jams or sticks within its normal travel, turn the lead-screw spur gear and watch the movement of the carriage. If it always jams or sticks at one place on the lead screw, inspect the screw threads for dirt or damage. Embedded particles may be removed or slightly damaged threads repaired without disassembly. To repair a badly damaged or bent screw, the unit should be disassembled.

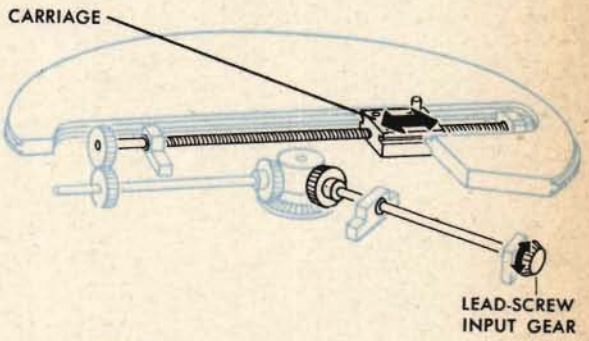
If the lead screw is undamaged, examine the guides in the vector slot for damage. Remove any high spots on the carriage guides by polishing with crocus cloth wrapped around a steel block.

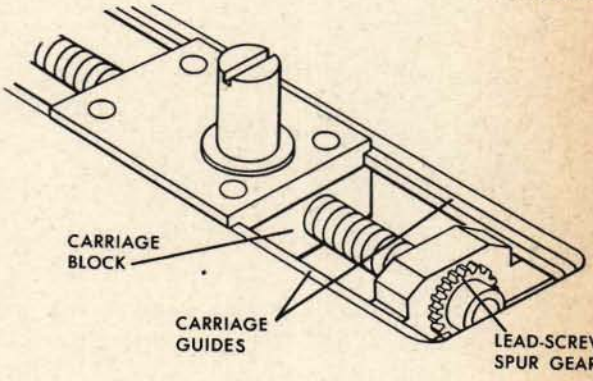
A badly damaged or bent lead screw may cause the block to stick throughout its travel. It is necessary to disassemble the unit in order to repair or replace the lead screw.

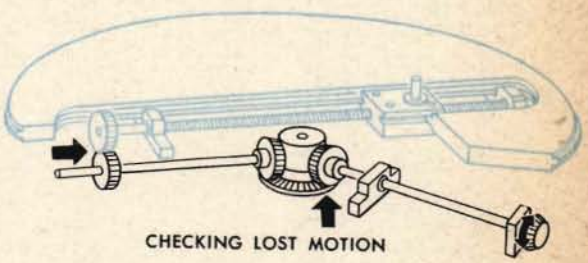
If the lead screw and carriage operate normally, the trouble may be caused by jammed gears, a bent shaft, or a defective bearing in the shaft line under the vector gear. Turn the lead-screw input gear back and forth to check for lost motion between the two spur gears and also between each of the bevel pinions and the central bevel gear.

Tight bevel gears can usually be freed by repositioning the hangers. These hangers may have shifted because of an incorrectly adjusted limit stop in the vector-gear input shaft line. The instrument OP gives directions for adjusting this limit stop.





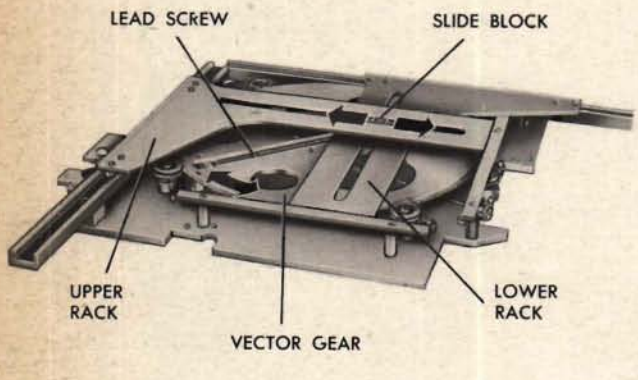




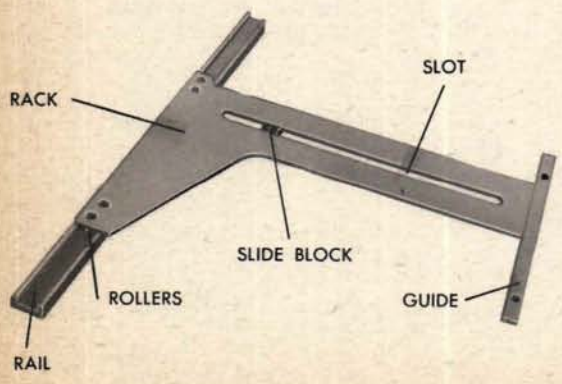
Vector gear: jamming or sticking

A vector gear may jam or stick because of dirty or damaged gear teeth, guide rollers, or guiding surfaces. Often the vector gear may be turned from its jammed position and the damage repaired without disassembling the unit. Dirt in the bearings of the guide rollers also may cause sticking. To clean the bearings, the rollers must be removed. This requires disassembling the unit.

The vector gear may not turn or may turn sluggishly because the slide blocks jam or stick on the pivot stud. The slide block in the upper rack may be removed without disassembling the entire unit.



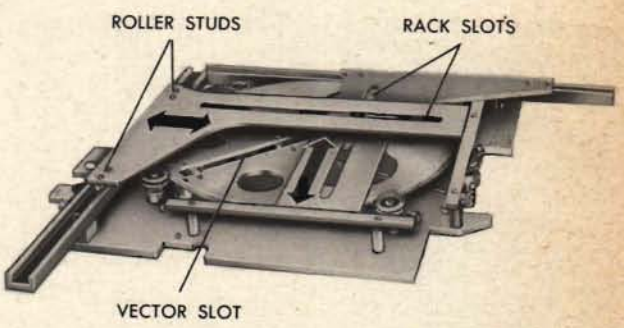
Racks: jamming or sticking



A rack may jam or stick because of a dirty or damaged rack guide, guide rail, rack roller, rack slot, slide block, or damaged gear teeth. Slight damage may be repaired and the parts cleaned and lubricated without disassembling the unit. Improper positioning of rollers may cause them to jam or stick in a rail, or may make too tight a mesh between the rack and pinion. Shake the rack to check lost motion between the rollers and the rail. Usually a slide block which sticks slightly in a rack slot may be restored to normal operation by cleaning and lubricating the sliding surfaces and running the parts back and forth to work them in smoothly.

Excessive lost motion

Excessive lost motion between the racks and their guide rails may be caused by damaged rollers or by loose or damaged roller studs.



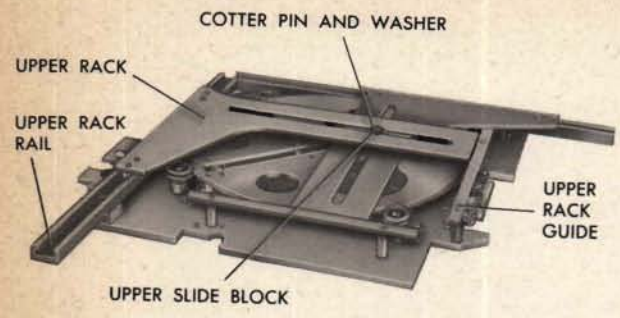
Move the carriage to one end of its travel on the lead screw. Position the vector gear at various angles and shake the racks at each position. Lost motion between the racks and the lead screw may be caused by a worn slide block or slot, or by a worn carriage or vector slot. Such lost motion can be remedied only by replacing the worn parts. Disassembly of the unit is necessary.

To check for excessive lost motion or side play of the vector gear, shake the gear. Any noticeable side play is caused by improper adjustment of the four guide rollers. To eliminate the excessive side play, the unit must be disassembled to reposition the roller studs. The side play must be removed without disturbing the centering of the vector gear. See page 268.

CHECKING THE VECTOR GEAR FOR SIDE MOTION

Slipping

If the racks do not move when the vector-gear or lead-screw input shaft is turned, the trouble may be caused by the fact that the lead screw threads are stripped, the pivot stud is broken, or the taper pin is missing from a gear hub. It will probably be necessary to disassemble the unit to make repairs.

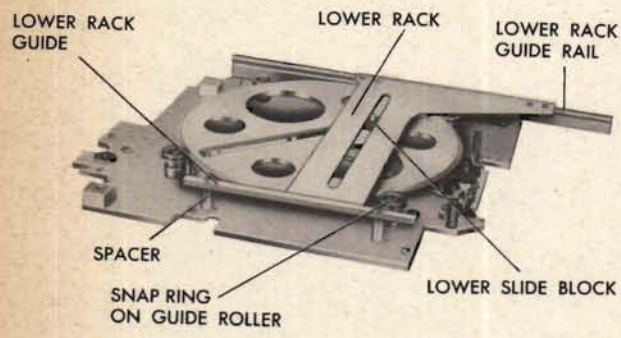


Disassembling the unit

1 Remove the cotter pin and washer from the stud.

2 Remove the screws holding the upper rack guide and rack rail, and lift off the rack, rack rail, and rack guide together.

3 Remove the upper slide block from the pivot stud. Keep the block with the rack.

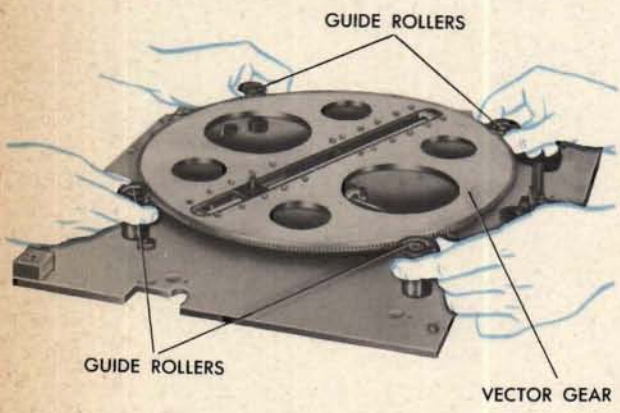


4 Remove the lower rack, rack rail, rack guide, and spacers.

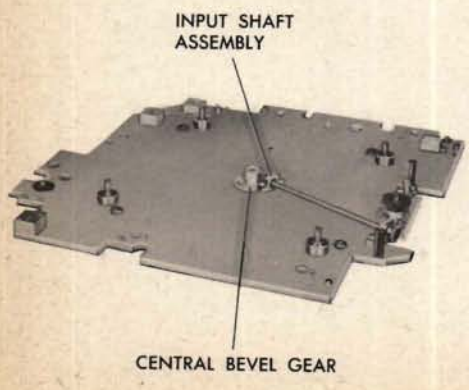
5 Remove the lower slide block.

6 Remove the snap rings from the four guide-roller studs.

7 To insure correct reassembly, mark each stud and its guide roller. Remove and tag each spacer with the identifying number of its stud.



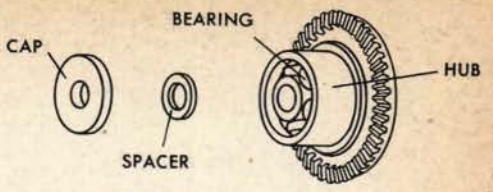
8 Being careful not to cock the gear, lift off the four guide rollers and the vector gear. This operation requires two men.



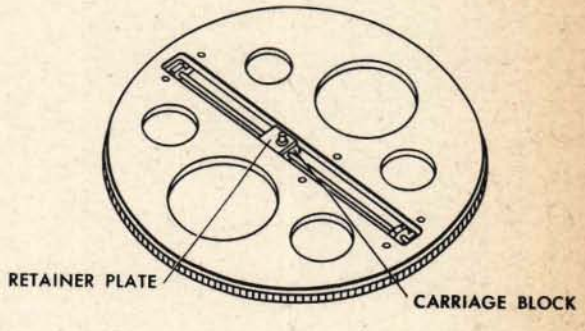
9 Remove the input shaft assembly from the plate by taking out its hanger screws.

10 Remove the flat-head screw and central bevel gear.

11 Remove the cap from the hub of the central bevel gear and lift out the spacer and bearings.



12 Take the retainer plate off the carriage block by removing the four socket-head screws.

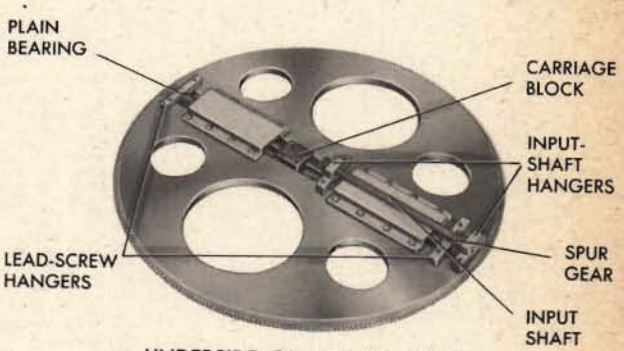


13 Remove the input shaft and hangers from the vector gear.

14 Remove the screws from the lead-screw hangers.

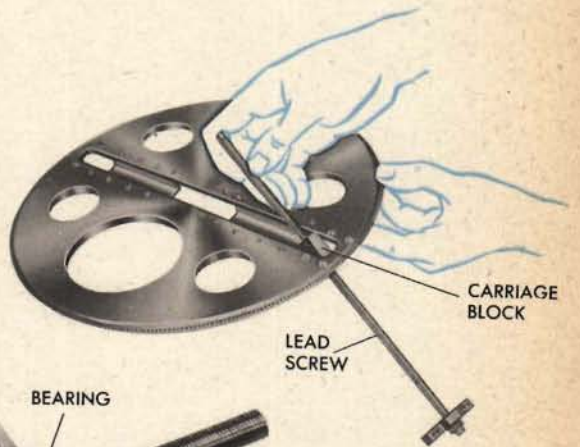
15 Remove the lead-screw hanger which acts as a plain bearing.

16 Turn the carriage block 90°.

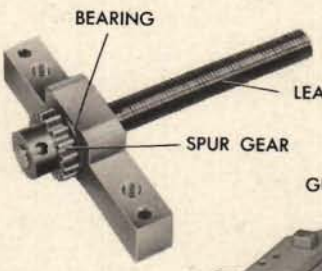


UNDERSIDE OF VECTOR GEAR

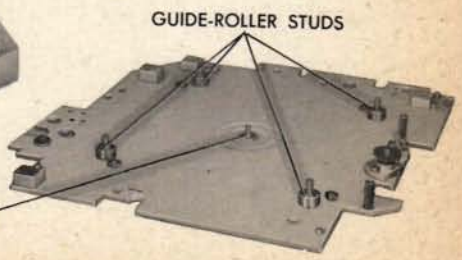
17 Slide the carriage block and the lead screw out of the vector gear.



18 If the lead screw or lead-screw ball bearings must be replaced, unpin the spur gear, remove it with its spacer, and slide out the lead screw. Tap the bearings out of the hanger.



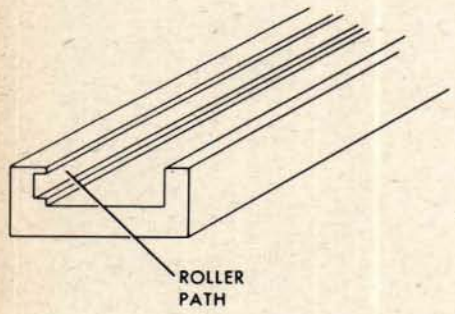
19 Do not remove the four guide-roller studs unless they must be readjusted for the purpose of recentering the vector gear or for removing excessive side play from the vector gear. If the studs are removed, mark the plate and tag the shims to insure correct reassembly. (Refer to step 7.)



20 Do not remove the center stud unless it must be replaced.

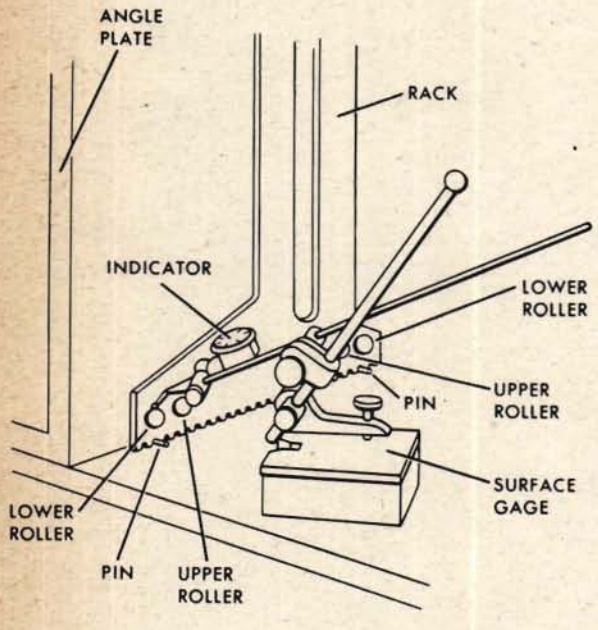
Repairing the parts

Repairing a rail



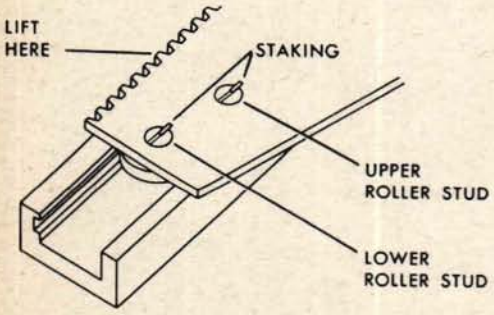
First use tissue to clean the roller path in the rail. Carefully remove any embedded foreign material. Then check the straightness of the roller path and, if necessary, polish rough or high spots with crocus cloth, trying the rack in the rail frequently until a good fit is obtained. After completing this work, wash the parts thoroughly with an approved solvent and lubricate them.

Repositioning rack rollers



The lower rollers establish the pitch line of the rack in relation to its meshing gear. These rollers affect the alignment of the rack slots as well as the mesh of the rack and the gear. Remove the rack and mount it against an angle plate on a surface plate. Support the rack under its teeth with two identical pins between 0.070 and 0.075 inch in diameter. Place one pin under each end of the rack. With a surface gage and a dial indicator, measure the height of the lower rollers. The heights of these rollers must agree with the assembly drawing and be within 0.0002 inch of each other. If these rollers are repositioned, the rack slots must be checked for squareness.

The upper rollers control the play between the rack and its rail. The play should not exceed 0.0005 inch. A strip of feeler gage material (0.001 inch) can be used as a "no go" gage to check the clearance between the roller and the roller path.



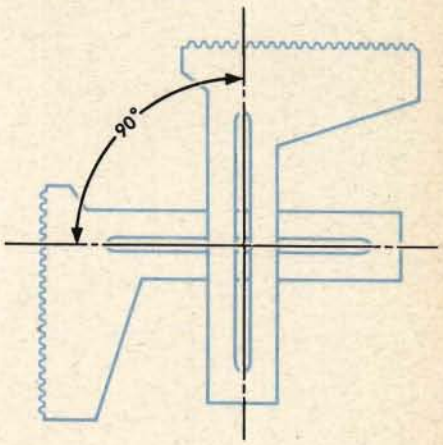
To position the rollers, turn the roller studs with a screw driver. Then stake a small amount of metal into the screw driver slots of the stud heads.

The rollers should be free enough in the rail for the rack to drop back of its own weight if it is raised slightly with one finger.

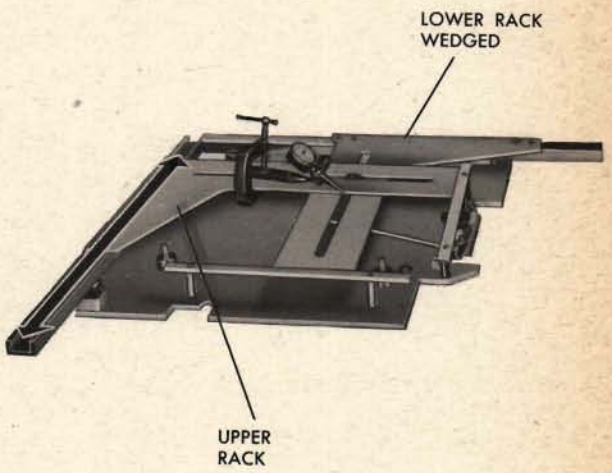
For an explanation of the proper method of removing and replacing a riveted stud, see pages 77-79.

Squaring the racks

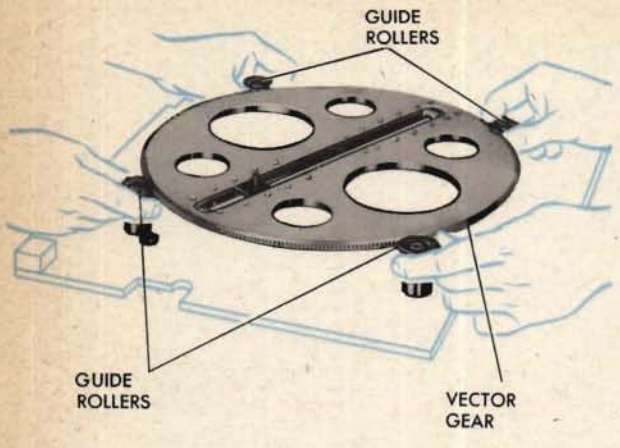
The slots in the upper and lower racks must be at right angles to each other.



Reassemble on the plate the two racks, their rails and guides. The vector gear should not be installed for this operation. Wedge the lower rack to prevent it from moving.



Mount a dial indicator firmly on the top rack with its point on one face of the lower rack slot. Move the upper rack through its full travel and observe the reading as the point of the indicator moves along the face of the slot in the lower rack. If the total reading exceeds 0.002 inch, check the setting of the lower rollers on the lower rack as instructed on page 266. It is advisable to check the lower rollers of the upper rack at the same time. Replace the two racks and repeat the check for squareness. If the indicator reading still exceeds 0.002 inch, reposition one of the rails. To do this, first drive the dowels out of the rail. Then replace the rail and its rack and repeat the check for squareness. If the indicator reading is still excessive, loosen the screws holding the rail, and move the rail within the clearance of its screw holes until a reading of 0.002 inch or less is obtained. Then tighten the screws and redowel the rail with oversize dowels.

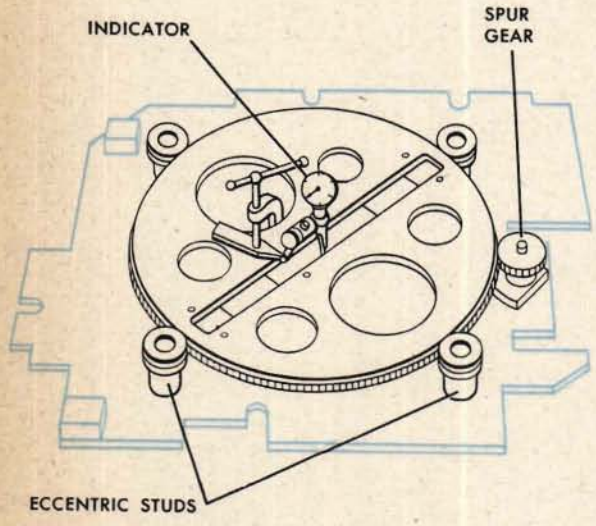


Positioning the vector gear

Centering the vector gear about the center stud and controlling the side play of the vector gear are accomplished by adjusting the eccentric studs which support the guide rollers.

First disassemble the unit as directed on pages 264 and 265. Remove the guide-roller studs, and drive out the dowels which hold them in place. Replace the studs, taking care to put them in their original holes. Then remount the vector gear, leaving off the lead screw and the central bevel gear.

Now clamp an indicator firmly on the vector gear with its point against the stud which supports the central bevel gear. Turn the vector gear one revolution, observing the variation in the indicator reading. This checks the vector gear and center stud for concentricity. If the total indicator reading exceeds 0.002 inch, adjust the guide-roller studs to center the vector gear. Turn the vector gear one revolution to check the concentricity again. At the same time, check that the vector gear turns freely with no more than 0.0005 inch side play. If the side play is excessive, adjust the studs accordingly, but recheck the concentricity after this adjustment is made.



INDICATOR POINT TOUCHING CENTRAL BEVEL GEAR STUD

The vector gear may stick at one point and have excessive side play at another point because of damage to its guiding surfaces. Remove high spots or imbedded particles from the guiding surfaces by careful use of a scraper.

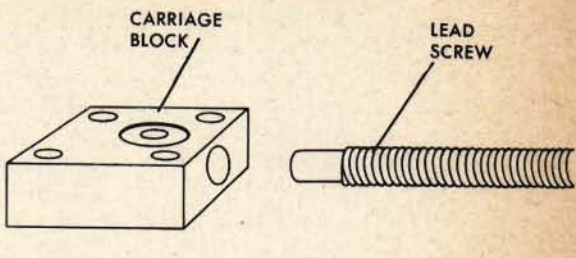
After the vector gear has been positioned satisfactorily, turn the unit over, stake the stud nuts and dowel the studs to the plate.

Adjusting the mesh between the vector gear and its spur gear

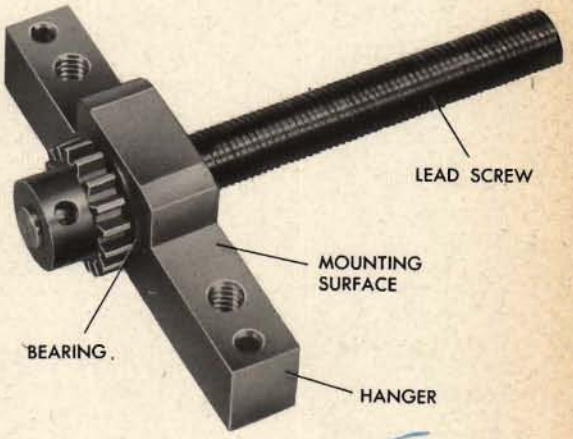
If there is excessive lost motion between the vector gear and the spur gear which drives it, the spur gear should be repositioned. *Never* move the vector gear to reduce such lost motion. Doing so will disturb the concentricity of the vector gear about the center stud.

Replacing a lead screw or a carriage block

Before starting a lead screw into a carriage block, make sure that no dirt or chips have been picked up in handling the parts. Then, using an approved lubricant, lubricate both parts and start the lead screw carefully into the unthreaded end of the hole in the block. Run the whole length of the screw through the block to see that it travels smoothly.



Mount the lead screw in the hanger containing two bearings. Pin the spur gear to the shaft, using a suitable spacer between the gear and the bearing to control the end shake. The end shake of the lead screw in the bearings must be kept at a minimum, because the total end shake of the lead screw and carriage block should not exceed 0.0015 inch after mounting on the vector gear.



Mount the lead screw and carriage block in the vector-gear slot.

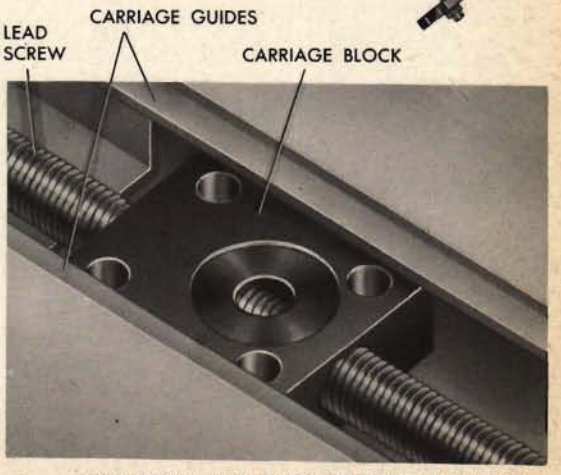
Turn the lead screw to move the carriage block the entire length of the slot. The block should slide freely, just touching the under sides of the carriage guides.

If the block does not touch both guides at the same time, one or both of the bearings supporting the ends of the lead screw is too high. Reduce the height of a bearing by scraping the mounting surface of the hanger; otherwise the lead screw will bind when the retainer plate is attached to the carriage block.

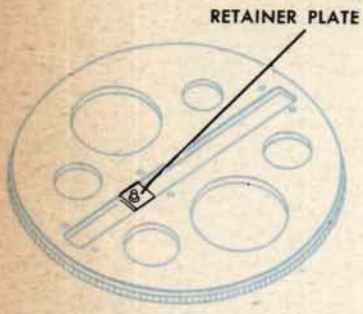
MOUNTING THE LEAD SCREW AND CARRIAGE BLOCK ON THE VECTOR GEAR

If, with each turn of the screw, the block alternately presses against and moves away from the guides, the screw probably is bent. A bent lead screw should be replaced, but if no spare is available and the lead screw is made of aluminum, it can sometimes be straightened by hand sufficiently to be used temporarily.

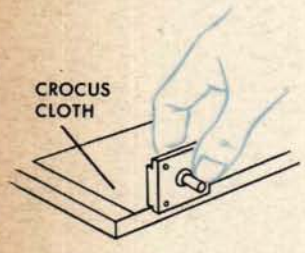
If the block fits tightly against the guides throughout its travel and causes the lead screw to bind, particularly when the block is near the ends of the lead screw, remove the block and polish the top of it on crocus cloth laid flat on a surface plate until the proper fit is obtained.



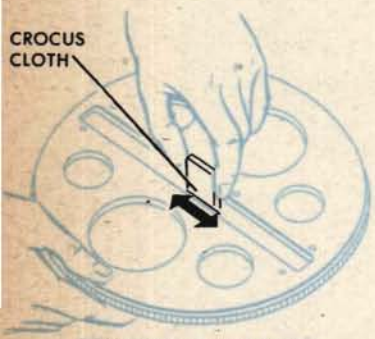
LEAD SCREW AND CARRIAGE BLOCK MOUNTED



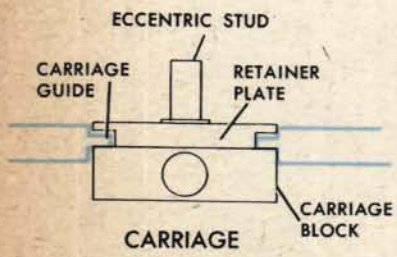
TESTING THE RETAINER PLATE ON THE GUIDES



POLISHING THE SIDES OF A RETAINER PLATE



POLISHING INNER FACES OF CARRIAGE GUIDES



Fitting a new retainer plate

In fitting a new retainer plate, first rivet a new pivot stud in place. (Follow the directions for riveting and positioning eccentric roller studs on page 78.) Then use a fine oilstone to remove any sharp "feather" edges. Stone sparingly, as it is important not to round or chamfer the edges.

With the lead screw and the carriage block removed, try the retainer on the carriage guides. If necessary, polish the sides of the retainer on crocus cloth until it fits without lost motion in the widest part of the space between the carriage guides. Remove equal amounts from each side so that the stud hole remains centered. During this operation do not remove material from any surface of the retainer except the sides which fit between the guides. Measure the retainer occasionally with a micrometer to be certain that the sides are parallel.

Polish the inner faces of the carriage guides with crocus cloth backed up by a steel bar until the retainer can be moved freely through the full length of the vector gear slot. Keep the sides square and flat. Clean the guides and the retainer thoroughly each time before trying them together. Apply a little approved lubricant and move the retainer back and forth by hand until it travels smoothly from one end to the other.

Mount the retainer on the carriage block in the vector gear slot. Tighten each of the four screws a little at a time. Each time the screws are tightened, slide the carriage back and forth on the guides.

If the slots in the carriage are too narrow, the carriage will clamp tightly on the guides when the screws are tightened. Remove the retainer and polish the lips which ride on the upper faces of the guides until the carriage can be moved over the thinnest portion of the guides. Then, if necessary, polish the upper faces of the guides to fit the slots in the carriage.

If the slots in the carriage are too wide, the carriage will fit loosely. (The clearance should be between 0.0005 and 0.0011 inch.) Polish the bottom of the retainer to reduce the width of the slots.

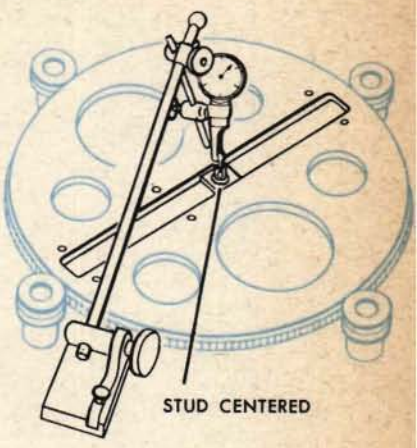
After a retainer has been fitted, clean and lubricate the lead screw, the carriage, and the carriage guides with approved solvents and lubricants. Mount the lead screw and the carriage on the vector gear. Turn the lead screw, and check the freedom of the carriage as it travels from one end of the slot to the other. If it drags, probably the lead screw is pulling the carriage against one guide. Remove the lead screw and drive the dowels out of the vector gear. Remount the lead screw and position the hangers so that the carriage moves smoothly through its entire travel. Tighten the screws; redowel the hangers to the vector gear with oversize dowels; lubricate the parts again, and make a final check for smoothness of travel.

Centering the pivot stud

Position the carriage so that the eccentric pivot stud lies directly above the central bevel gear and hold it in this position by wedging the spur gear at the end of the lead screw.

Mount a surface gage and dial indicator as shown in the accompanying illustration. Turn the vector gear one revolution, observing any changes in the indicator reading. If the total changes in the reading exceed 0.002 inch, compensate first by repositioning the carriage and then by adjusting the eccentric stud.

Remove the retainer plate and stake the stud in place. Tap lightly, supporting the retainer plate directly under the staking tool. A heavy blow may warp the retainer.



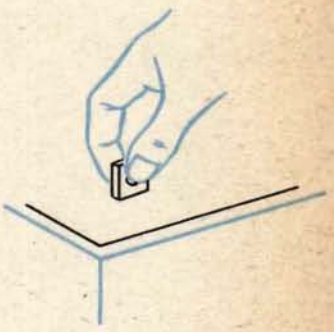
STUD CENTERED

Fitting a new slide block

Use a fine oilstone to smooth burred and rough edges of the slide block. Remove any extremely sharp edges but leave them square. It is very important not to round or chamfer the edges.

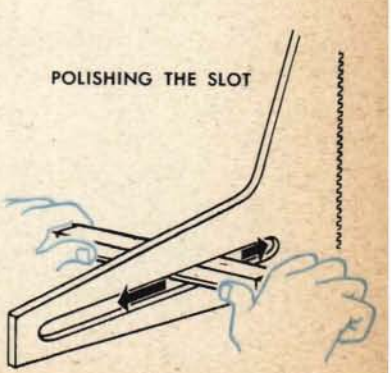
To reduce the width of the block, polish the sides on a piece of crocus cloth placed on a flat surface, using long, even strokes while holding the block square. Be sure to remove equal amounts from each side, so that the hole remains perfectly centered. Measure the block occasionally with a micrometer to be certain that the sides are parallel.

Polish the block until it fits closely in the widest portion of the slot. Polish the rest of the slot to fit the block, using crocus cloth wrapped once around a steel bar. Be sure to keep the slot sides square and flat. Before trying the block in the slot, thoroughly wash, dry and lubricate them both. The fit is correct when the block can be moved the full length of the slot. Move the block back and forth by hand until it travels smoothly from one end to the other. Finally, wash the slot and block again, and lubricate the slot.



POLISHING THE SLIDE BLOCK

POLISHING THE SLOT



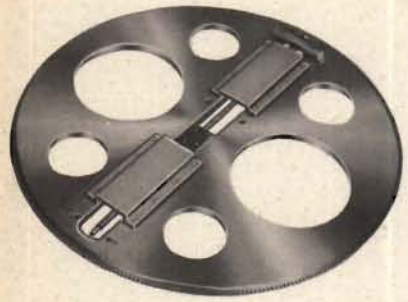
Repairing the shaft lines

For a detailed explanation of checking bearings, straightening shafts, and removing end play and lost motion from shaft assemblies, see *Basic Repair Operations.*

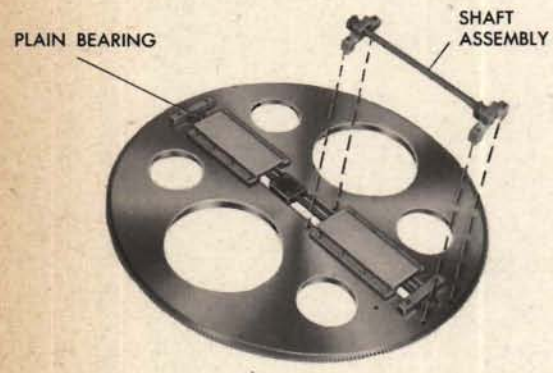
Reassembling the unit

Wash all the parts with an approved solvent, and then dry them. Lubricate each part as it is replaced.

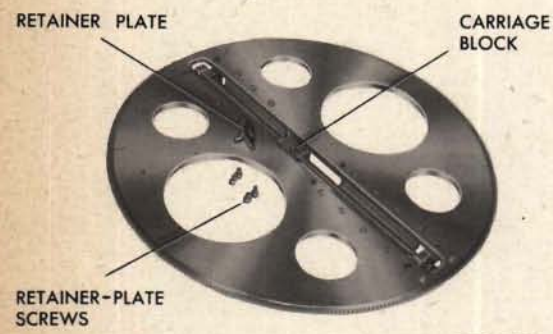
1 First making certain that the lead screw was started into the unthreaded end of the hole in the carriage block, place the lead screw in the vector-gear slot with the block in the position shown.



2 Replace the hanger which acts as a plain bearing, and secure both hangers to the vector gear.

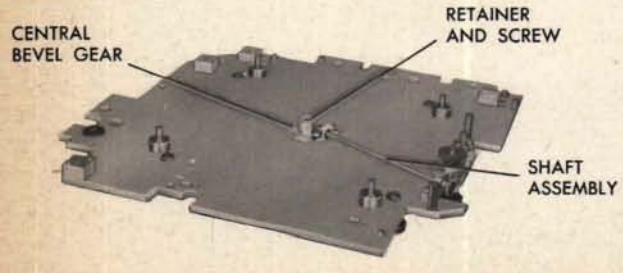


3 Replace the shaft assembly on the vector gear.



4 Replace the retainer plate on the carriage block. (Check that the pivot stud is staked.)

5 Replace the bearings in the central bevel gear hub and mount the gear on its stud.



6 Replace the spacer and the cap on the stud, and hold them down with a flat-head screw.

7 Replace the shaft assembly on the plate.

8 Place the four rollers around the vector gear, and lower the rollers as shown, each one on its respective stud. Replace each spacer on its proper stud. (These parts should have been given identifying marks when disassembled.)

9 Secure the guide rollers on the studs with snap rings.

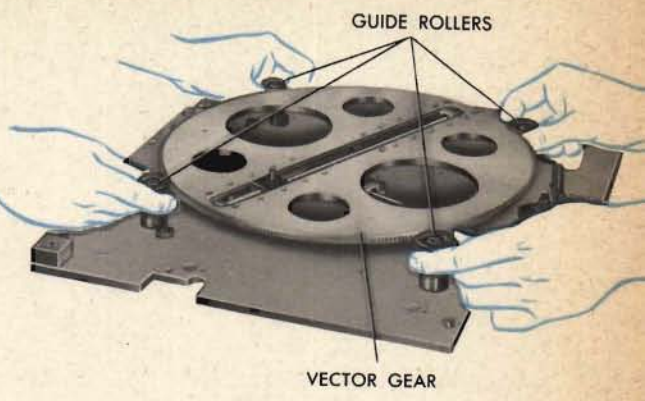
10 Put the lower slide block on the pivot stud.

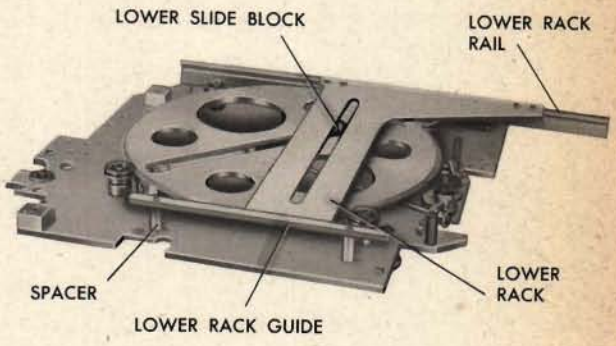
11 Put the lower rack, rail, and guide in place, with the lower slide block in the rack slot. Replace the spacers under the rack guide, and then secure both the guide and the rail to the plate.

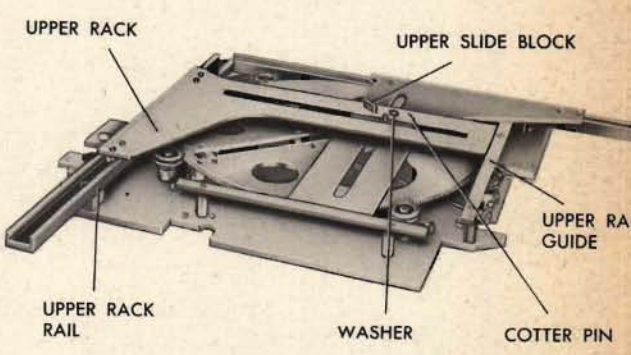
12 Put the upper slide block on the pivot stud.

13 Put the upper rack, rail, and guide in place, with the slide block in the rack slot. Secure the rack guide and rail to the plate.

14 Secure the slide blocks on the pivot stud with a washer and a cotter pin.







Bench checking the unit

1 Check the assembly of the unit against the assembly drawing.

2 To check for smoothness and for correct lost motion, move the racks through their full travel by turning the vector gear when the carriage is at one end of the lead screw. The bevel-gear hangers limit the rotation of the vector gear. Do not strike them.

3 Check that the pivot stud may be brought to a zero point where there is no motion of the racks when the vector gear is turned.

4 Check that the rotation of the vector gear is stopped only when the bevel-gear hangers touch. Make this test with the carriage at both ends of its travel.

5 Check that the carriage cannot be moved along the slot more than 0.0015 inch.

6 Check that the lead screw and the connected shaft lines turn freely throughout the travel of the carriage.

7 Check that the slots in the racks are at right angles to each other.

8 Check that the lost motion between the racks and their rails is no more than 0.002 inch.

9 Check that the eccentric studs in the racks have been staked.